DRAFT

TMDL Development
Middle Clinch River Watershed, VA

Prepared for:
Virginia Department of Environmental Quality

Submitted by:
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Background and Applicable Standards

There are fourteen (14) different impaired streams in this study area, Clinch River, Indian Creek, Weaver Creek, Thompson Creek, Lewis Creek, Hess Creek, Swords Creek, Little River, Big Cedar Creek, Burgess Creek, Dumps Creek, Elk Garden Creek, Loop Creek and Maiden Spring Creek and twenty (20) separate impaired segments.

All 20 segments have bacterial impairments. Table ES.1 shows the details of these impairments.

In Virginia, once a water body violates a given standard, a Total Maximum Daily Load (TMDL) must be developed. The TMDL is a pollution budget that determines the amount of pollutant the water body can receive in a given period of time and still meet the intended standard.

Table ES.1 Impairments within the Middle Clinch River watershed included in this study.

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles**	**2010 Listing Violation%**	**Impairment Location Description**
Indian Creek VAS-P05R_IDN01A04	*E. coli*	2004	3.98	16 EC	From the highway 19 crossing to the Little River confluence at Wardell.
Clinch River VAS-P07R_CLN01A00	*E. coli*	2002	13.95	18 EC	From its confluence with Big Cedar Creek near Pinnacles downstream to its confluence with Dumps Creek at Carbo.
Big Cedar Creek VAS-P06R_BCD01A98	*E. coli*	2006	4.11	33 EC	From the vicinity of Daughertys Cave downstream to confluence with Clinch River.
Big Cedar Creek VAS-P06R_BCD02A02	*E. coli*	2008	1.12	33 EC	From the confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave.
Big Cedar Creek VAS-P06R_BCD02A00	*E. coli*	2006	2.75	25 EC	From the Lebanon raw water intake downstream to the confluence with Little Cedar Creek.
Big Cedar Creek VAS-P06R_BCD03A00	*E. coli*	2006	3.23	67 EC	From its headwaters downstream to the Lebanon raw water intake.
Loop Creek VAS-P06R_LOO01A06	*E. coli*	2006	2.87	50 EC	From route 80 downstream to the Elk Garden Creek confluence.
Burgess Creek VAS-P06R_BUG01A06	*E. coli*	2006	1.50	67 EC	From its confluence with Campbell Branch to its confluence with Big Cedar Creek.
Elk Garden Creek VAS-P06R_EKG01A06	*E. coli*	2006	3.28	75 EC	From Elk Garden to its confluence with Big Cedar Creek.
Weaver Creek VAS-P07R_WEA01A06	*E. coli*	2006	9.14	50 EC	From it's confluence with Hart Creek to its confluence with the Clinch River near Artrip
Thompson Creek VAS-P07R_TMP01A06	*E. coli*	2006	4.26	50 EC	From Coulwood to its confluence with the Clinch River.

EC Based on the instantaneous *E. coli* standard of 235 cfu/100mL.

ES.1 Impairments within the Middle Clinch River watershed included in this study (cont.).

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles**	**2010 Listing Violation%**	**Impairment Location Description**
Lewis Creek VAS-P04R_LWS01A98	*E. coli*	2006	4.83	33 EC	From it's confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence.
Lewis Creek VAS-P04R_LWS01A10	*E. coli*	2010	3.43	33 EC	From it's confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock.
Hess Creek VAS-P04R_HES01A10	*E. coli*	2010	1.04	41 EC	From groundhog hollow downstream to just south of Dye.
Swords Creek VAS-P04R_HES01A10	*E. coli*	2010	2.88	25 EC	Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence.
Little River VAS-P05R_LTR02A00	*E. coli*	2004	5.18	50 EC	From the Claypool Hill STP downstream to Laurel Creek confluence near Wardell.
Little River VAS-P05R_LTR02A02	*E. coli*	2008	4.11	50 EC	From the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line.
Dumps Creek VAS-P08R_DUM01A94	*E. coli*	2006	3.41	16 EC	From the Hurricane Creek confluence downstream to Clinch River confluence at Carbo.
Maiden Spring Creek VAS-P05R_MSC01A02	*E. coli*	2004	6.51	25 EC	From the Little River confluence upstream to foot of Morris Knob north of Robbins Gap.
Maiden Spring Creek VAS-P05R_MSC01C04	*E. coli*	2004	8.57	42 EC	From an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob.

EC Based on the instantaneous *E. coli* standard of 235 cfu/100mL.

TMDL Endpoint and Water Quality Assessment

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to E. coli values.

Source Assessment

Sources of bacteria were identified and quantified in the Middle Clinch River watershed. Sources included point sources as well as non-point sources. The quantification of sources is important to determine the baseline of current conditions that is causing the impairment. Sources of bacteria included human, livestock, wildlife, pets, as well as permitted point sources.

Modeling Procedures

Computer modeling is used to relate the sources on the ground to the water quality in the streams and rivers. This is important since not every colony of bacteria in the Middle Clinch River watershed ends up in the streams and rivers. The computer models help quantify the portion of bacteria within the Middle Clinch River watershed that ends up in the stream.

The computer modeling process consists of several steps. First, the characteristics of the drainage area including land use, slopes, stream network, soil properties, are entered into the model. The quantities of bacteria are also entered into the model. A process known as calibration is then conducted by comparing model simulations with monitored field data. Model parameters are adjusted during calibration to minimize the error between simulated and monitored values. This process is conducted for hydrology (flow) as well as water quality. Once the model is calibrated, it is then used to determine the existing water quality conditions in the study area and may be used to determine the reductions necessary to meet the water quality standard or endpoint.

Hydrology

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads. For purposes of modeling the Middle Clinch River watershed, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into twenty-one (21) subwatersheds.

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct sources of uncontrolled discharges, direct deposition by wildlife, direct deposition by livestock, and direct inputs from sewer overflows. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

Load Allocation Scenarios

The next step in the TMDL processes was to reduce the various source loads to levels that would result in attainment of the water quality standards or endpoints. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL information is shown in Table ES.2.

The final bacterial TMDLs for the Middle Clinch River watershed include 100% reductions in straight pipes and sewer overflows.

Table ES.2 Average annual in-stream cumulative pollutant loads modeled after allocation in the Middle Clinch River watershed impairments.

Pollutant	Units	Impairment	WLA[1]	LA	MOS	TMDL
E. coli	cfu/yr	Swords/Hess Creek	7.03E+12	6.94E+14	*Implicit*	7.01E+14
E. coli	cfu/yr	Lewis Creek	1.53E+13	4.88E+14	*Implicit*	5.03E+14
E. coli	cfu/yr	Dumps Creek	9.90E+12	9.80E+14	*Implicit*	9.90E+14
E. coli	cfu/yr	Elk Garden/Loop	6.36E+12	6.29E+14	*Implicit*	6.35E+14
E. coli	cfu/yr	Big Cedar/Burgess	1.34E+13	1.17E+15	*Implicit*	1.18E+15
E. coli	cfu/yr	Clinch River	1.60E+13	1.51E+15	*Implicit*	1.53E+15

[1] WLA by permit can be found in the corresponding allocation chapters.

Implementation

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in the Middle Clinch River watershed. The next step will be development of a TMDL implementation plan (IP), required by Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA). The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned, a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

During development of the TMDL for the impairments in the Middle Clinch River watershed study area, public involvement was encouraged through a first public meeting (05/26/2011), and a final public meeting (05/24/2012). An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the Middle Clinch River watershed TMDLs were presented at the first of the public meeting. Public understanding of and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting. Written comments were addressed in the final document.

1. INTRODUCTION

1.1 Regulations Background

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the six designated uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, the stream is "listed" in the current Section 303(d) report as requiring a Total Maximum Daily Load (TMDL). Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a stream; that is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *"Board shall develop and implement a plan to achieve fully supporting status for impaired waters"*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

1.2 *Middle Clinch River and Tributaries Watershed Characteristics*

The Middle Clinch River watershed (USGS Hydrologic Unit Code 06010205) is located in Russell and Tazewell Counties of Virginia. This watershed is a part of the Tennessee/Big Sandy River basin, which drains via the Mississippi River to the Gulf of Mexico. The location of the watershed is shown in **Figure 1.1**. The drainage area flowing into the most downstream impairment in this project is approximately 384,180.

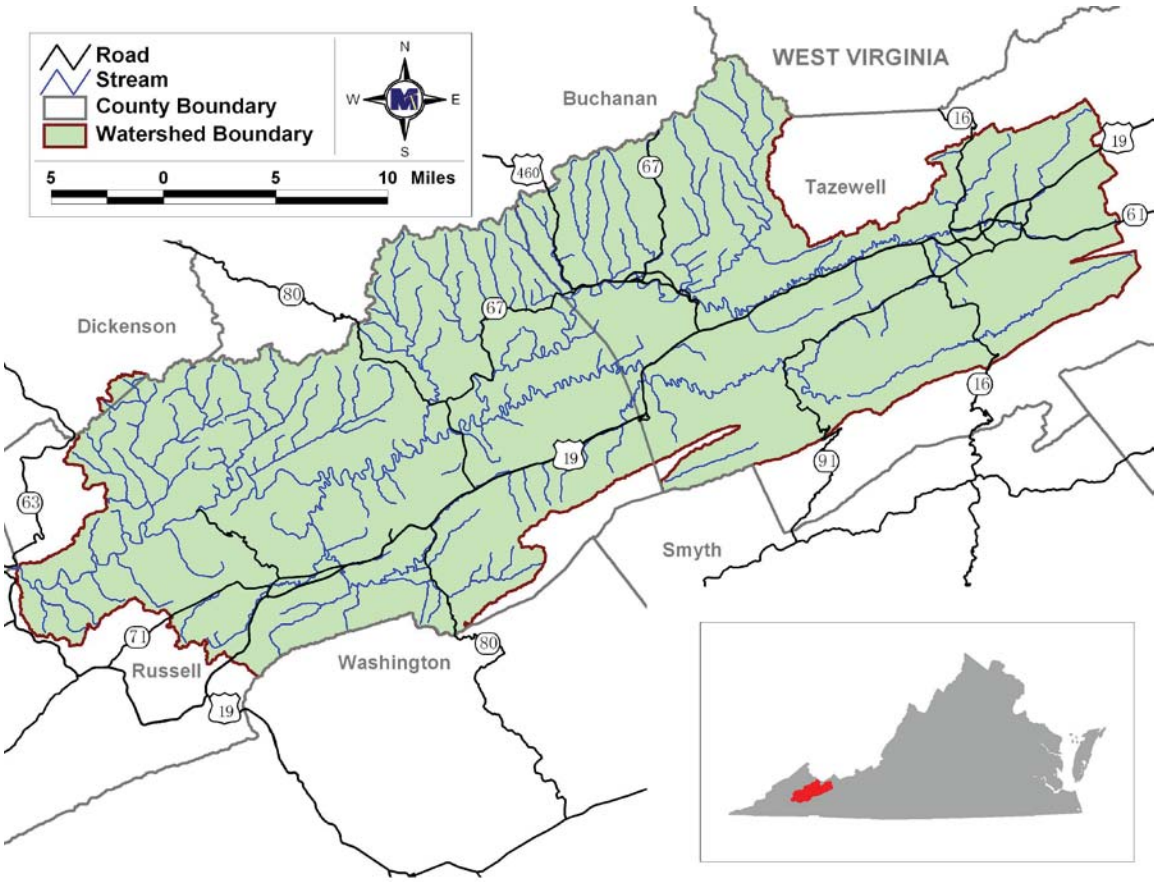

Figure 1.1 Location of the Middle Clinch River watershed.

The Middle Clinch River watershed is located within the level III Central Appalachian (69) and Ridge and Valley (67) ecoregions. The Central Appalachian ecoregion is a high rugged plateau consisting of sandstones, shale, conglomerate and coal. Some valleys contain limestone. Elevations range from 1,200 to 4,600 feet.

The Ridge and Valley ecoregion has elevations from 500 to 4,300 feet. The geology is primarily sedimentary sandstones, shale and limetone. (http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_%28EPA%29).

As for the climatic conditions in the Middle Clinch River watershed, during the period from 1896 to 2010 Burkes Garden, Virginia (NCDC station# 441209) received an average annual precipitation of 45.14 inches, with 52% of the precipitation occurring during the May through October growing season (SERCC, 2011). Average annual snowfall is 42 inches, with the highest snowfall occurring during January (SERCC, 2011). The highest average daily temperature of 78.6 ºF occurs in July, while the lowest average daily temperature of 21.6 ºF occurs in January (SERCC, 2011).

Land use in the study area was characterized using the National Land Cover Database 2001 (NLCD). The drainage area is predominantly forest with woodlands covering approximately 59% of the area. Pasture and hay land covers account for roughly 30% of the drainage area. Developed, grassland, cropland, and water land uses account for the remainder of the study area.

1.3 Middle Clinch River Watershed Recreation Use Impairments

There are twenty (20) different impairment segments in this study area. The impaired segments are on the following fourteen (14) streams: Clinch River, Indian Creek, Weaver Creek, Thompson Creek, Lewis Creek, Hess Creek, Swords Creek, Little River, Big Cedar Creek, Burgess Creek, Dumps Creek, Elk Garden Creek, Loop Creek and Maiden Spring Creek. In the sections below each impaired segment is described.

1.3.1 Clinch River (VAS-P07R_CLN01A00)

The Clinch River in Russell County flows southwest before it reaches the Virginia/Tennessee state line.

The Clinch River from its confluence with Big Cedar Creek near Pinnacles downstream to its confluence with Dumps Creek at Carbo (13.95 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BCLN271.50 showed an 18% *E. coli* bacteria standard violation rate in the 2010 assessment.

1.3.2 Indian Creek (VAS-P05R_IDN01A04)

Indian Creek in Russell County, VA flows northeast into the Little River at Wardell.

Indian Creek is listed as impaired from the route 19 bridge downstream to its confluence with the Little River (3.98 stream miles) on the 2010 303(d) list as impaired for not supporting the recreation/swimming use. VADEQ monitoring at station 6BIDN000.69 showed a 16% *E. coli* bacteria standard violation rate in the 2010 assessment.

1.3.3 Weaver Creek (VAS-P07R_WEA01A06)

Weaver Creek, in Russell County, VA flows southwest before its confluence with the Clinch River.

Weaver Creek from it's confluence with Hart Creek to its confluence with the Clinch River near Artrip (9.14 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring stations 6BWEA000.02 and 6BWEA004.32 both had a 50% violation rate in the 2010 assessment.

1.3.4 Thompson Creek (VAS-P07R_TMP01A06)

Thompson Creek, in Russell County, VA flows southwest before its confluence with the Clinch River at Artrip.

Thompson Creek from Coulwood to its mouth (4.26 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BTMP003.58 had a 50% violation rate in the 2010 assessment.

1.3.5 Lewis Creek (VAS-P04R_LWS01A98)

Lewis Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Lewis Creek from it's confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence (4.83 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLWS000.06 had a 33% violation rate in the 2010 assessment.

1.3.6 Lewis Creek (VAS-P04R_LWS01A10)

Lewis Creek from it's confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock (3.43 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLWS004.84 had a 33% violation rate in the 2010 assessment.

1.3.7 Hess Creek (VAS-P04R_HES01A10)

Hess Creek, in Russell County, VA flows southeast before its confluence with the Swords Creek.

Hess Creek from groundhog hollow downstream to just south of Dye (1.04 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BHES000.05 had a 41% violation rate in the 2010 assessment.

1.3.8 Swords Creek (VAS-P04R_SWD01A00)

Swords Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Swords Creek from the Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence (2.88 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BSWO001.81 had a 25% violation rate in the 2010 assessment.

1.3.9 Little River (VAS-P05R_LTR02A00)

Little River, in Russell and Tazewell Counties, VA flows southwest before its confluence with the Clinch River.

The Little River from the Claypool Hill STP downstream to Laurel Creek confluence near Wardell (5.18 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLTR018.19 had a 50% violation rate in the 2010 assessment.

1.3.10 Little River (VAS-P05R_LTR02A02)

The Little River from the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line (4.11 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLTR018.19 had a 50% violation rate in the 2010 assessment.

1.3.11 Big Cedar Creek (VAS-P06R_BCD01A98)

Big Cedar Creek, in Russell County, VA flows northwest before its confluence with the Clinch River.

Big Cedar Creek from the vicinity of Daughertys Cave downstream to confluence with Clinch River (4.11 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD001.89, had an *E. coli* bacteria standard violation rate of 33% in the 2010 assessment.

1.3.12 Big Cedar Creek (VAS-P06R_BCD02A02)

Big Cedar Creek from its confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave (1.12 miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD001.89, had an *E. coli* bacteria violation rate of 33% in the 2010 assessment.

1.3.13 Big Cedar Creek (VAS-P06R_BCD02A00)

Big Cedar Creek from the Lebanon raw water intake downstream to the confluence with Little Cedar Creek (2.75 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD006.66 had a violation rate of 25% in the 2010 assessment.

1.3.14 Big Cedar Creek (VAS-P06R_BCD03A00)

Big Cedar Creek from its headwaters downstream to the Lebanon raw water intake (3.23 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD009.83 had a violation rate of 67% in the 2010 assessment.

1.3.15 Maiden Spring Creek (VAS-P05R_MSC01A02)

Maiden Spring Creek, in Tazewell County, VA flows southwest before its confluence with the Little River.

Maiden Spring Creek from the Little River confluence upstream to foot of Morris Knob north of Robbins Gap (6.51 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BMSC001.53 had a 25% violation rate in the 2010 assessment.

1.3.16 Maiden Spring Creek (VAS-P05R_MSC01C04)

Maiden Spring Creek from an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob (8.57 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BMSC008.98 had a 42% violation rate in the 2010 assessment.

1.3.17 Loop Creek (VAS-P06R_LOO01A06)

Loop Creek, in Russell County, VA flows southwest before it’s confluence with Elk Garden Creek.

This impaired segment was listed on the 2010 303(d) list of impaired waters for not supporting the recreation/swimming use. This impaired segment extends from the Route

80 bridge downstream the Elk Garden Creek confluence (2.87 stream miles). VADEQ monitoring station 6BLOO004.25 had a bacteria standard violation rate of 50% in the 2010 assessment.

1.3.18 Burgess Creek (VAS-P06R_BUG01A06)

Burgess Creek, in Russell County, VA flows northeast before its confluence with Big Cedar Creek.

Burgess Creek from its confluence with Campbell Branch to its mouth (1.50 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBUG000.10 had a 67% violation rate in the 2010 assessment.

1.3.19 Elk Garden Creek (VAS-P06R_EKG01A06)

Elk Garden Creek, in Russell County, VA flows northeast before its confluence with Loop Creek (headwaters of Big Cedar Creek).

Elk Garden Creek from Elk Garden to its mouth (3.28 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BEKG004.18 had a 75% violation rate in the 2010 assessment.

1.3.20 Dumps Creek (VAS-P08R_DUM01A94)

Dumps Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Dumps Creek from the Hurricane Creek confluence downstream to the Clinch River confluence at Carbo (3.41 miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BDUM000.04 had a 16% violation rate in the 2010 assessment.

Figure 1.2 shows the location of the impairments in the Middle Clinch River Watershed. **Table 1.1** details the impairments in the Middle Clinch River watershed included in this study.

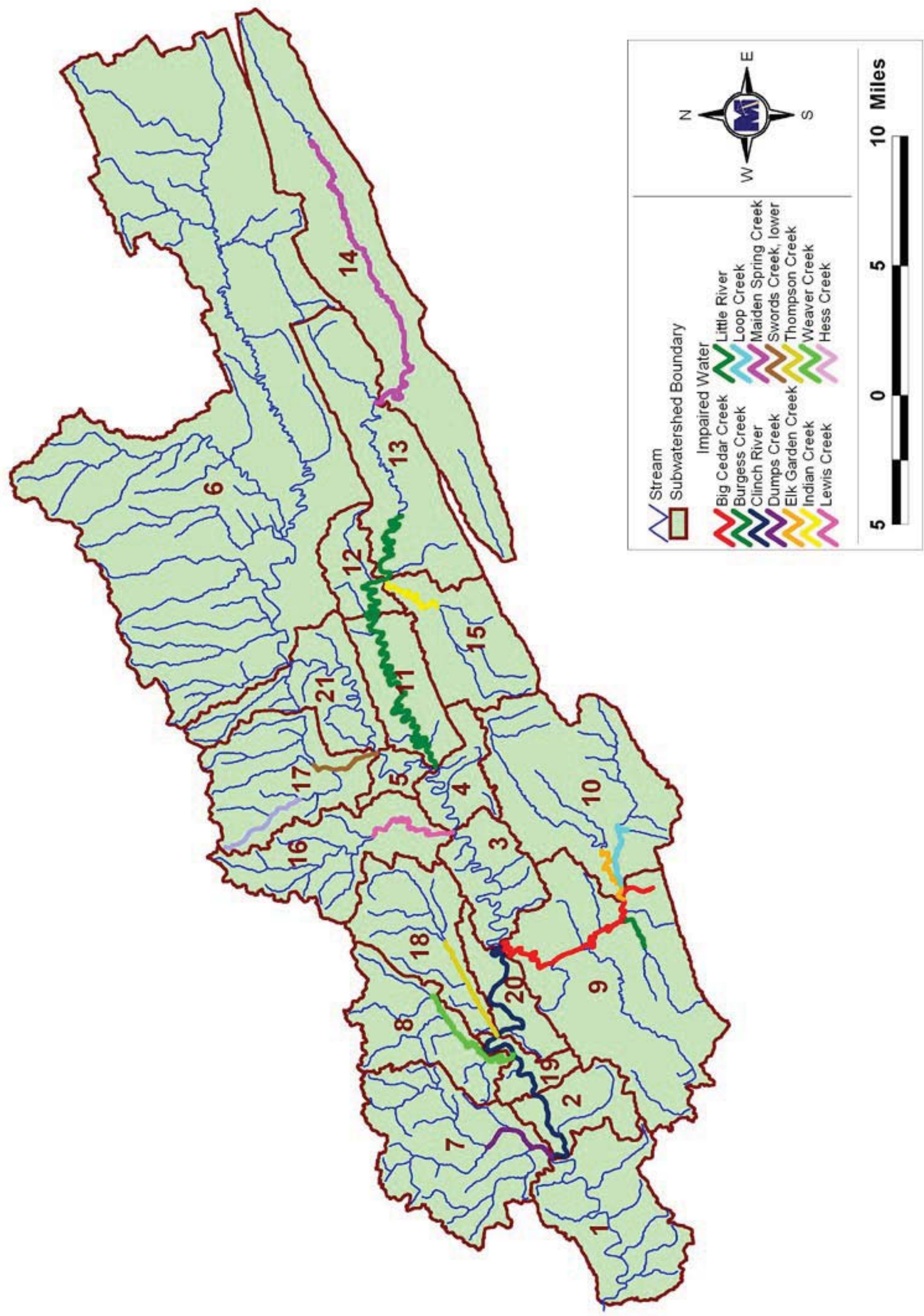

Figure 1.2 The impaired segments in the Middle Clinch River watershed.

Table 1.1 Impairments within the Middle Clinch River watershed included in this study.

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles**	**2010 Listing Violation%**	**Impairment Location Description**
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Big Cedar Creek VAS-P06R_BCD01A98	*E. coli*	2006	4.11	33 EC	From the vicinity of Daughertys Cave downstream to confluence with Clinch River.
Big Cedar Creek VAS-P06R_BCD02A02	*E. coli*	2008	1.12	33 EC	From the confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave.
Big Cedar Creek VAS-P06R_BCD02A00	*E. coli*	2006	2.75	25 EC	From the Lebanon raw water intake downstream to the confluence with Little Cedar Creek.
Big Cedar Creek VAS-P06R_BCD03A00	*E. coli*	2006	3.23	67 EC	From its headwaters downstream to the Lebanon raw water intake.
Loop Creek VAS-P06R_LOO01A06	*E. coli*	2006	2.87	50 EC	From route 80 downstream to the Elk Garden Creek confluence.
Burgess Creek VAS-P06R_BUG01A06	*E. coli*	2006	1.50	67 EC	From its confluence with Campbell Branch to its confluence with Big Cedar Creek.
Elk Garden Creek VAS-P06R_EKG01A06	*E. coli*	2006	3.28	75 EC	From Elk Garden to its confluence with Big Cedar Creek.
Weaver Creek VAS-P07R_WEA01A06	*E. coli*	2006	9.14	50 EC	From it's confluence with Hart Creek to its confluence with the Clinch River near Artrip
Thompson Creek VAS-P07R_TMP01A06	*E. coli*	2006	4.26	50 EC	From Coulwood to its confluence with the Clinch River.

EC - Based on the interim instantaneous *E. coli* standard of 235 cfu/100mL

Table 1.1 Impairments within the Middle Clinch River watershed included in this study (cont.).

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles**	**2010 Listing Violation%**	**Impairment Location Description**
Lewis Creek VAS-P04R_LWS01A98	*E. coli*	2006	4.83	33 EC	From it's confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence.
Lewis Creek VAS-P04R_LWS01A10	*E. coli*	2010	3.43	33 EC	From it's confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock.
Hess Creek VAS-P04R_HES01A10	*E. coli*	2010	1.04	41 EC	From groundhog hollow downstream to just south of Dye.
Swords Creek VAS-P04R_SWD01A00	*E. coli*	2010	2.88	25 EC	Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence.
Little River VAS-P05R_LTR02A00	*E. coli*	2004	5.18	50 EC	From the Claypool Hill STP downstream to Laurel Creek confluence near Wardell.
Little River VAS-P05R_LTR02A02	*E. coli*	2008	4.11	50 EC	From the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line.
Dumps Creek VAS-P08R_DUM01A94	*E. coli*	2006	3.41	16 EC	From the Hurricane Creek confluence downstream to Clinch River confluence at Carbo.
Maiden Spring Creek VAS-P05R_MSC01A02	*E. coli*	2004	6.51	25 EC	From the Little River confluence upstream to foot of Morris Knob north of Robbins Gap.
Maiden Spring Creek VAS-P05R_MSC01C04	*E. coli*	2004	8.57	42 EC	From an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob.

EC - Based on the interim instantaneous *E. coli* standard of 235 cfu/100Ml.

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act".

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Virginia adopted its current *E. coli* and *enterococci* standard in January 2003. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

The criteria which were used in developing the bacteria TMDL in this study are outlined in Section 9 VAC 25-260-170 and read as follows:

A. The following bacteria criteria (colony forming units (CFU)/100 ml) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:

E.coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater.
Enterococci bacteria shall not exceed a monthly geometric mean of 35 CFU/100 ml in transition and saltwater.
1. See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.
2. Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.
3. If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E.coli CFU/100 ml .
4. If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 CFU/100 ml.
5. For beach advisories or closures, a single sample maximum of 235 E.coli CFU/100 ml in freshwater and a single sample maximum of 104 enterococci CFU/100 ml in saltwater and transition zones shall apply.

2.2 Selection of a TMDL Endpoint

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the bacteria impairments in the Middle Clinch River Watershed, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard.

Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using the geometric mean standard. Therefore, the in-stream *E. coli* target for the TMDLs in this study was a monthly geometric mean not exceeding 126 cfu/100 ml.

2.3 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the Middle Clinch River Watershed. An examination of data from water quality stations used in the 303(d) assessment was performed. Sources of data and pertinent results are discussed.

2.3.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- Bacteria enumerations from twenty nine (29) VADEQ in-stream monitoring stations with data from January 1990 to February 2012,

2.3.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from January 1990 to February 2012 (**Figure 2.1**), were analyzed for fecal coliform (**Table 2.1**) and *E.coli* (**Table 2.2**). Samples were taken for the express purpose of determining compliance with the state instantaneous bacteria standards. Until recent years, and as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. E. coli concentrations have minimum and maximum laboratory detection concentrations of 25 and 2,000 cfu/100 mL respectively. Information in the tables is arranged in alphabetical order by stream name then from downstream to upstream station location.

Figure 2.1 Location of VADEQ water quality monitoring stations in the Middle Clinch River Watershed.

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1990 – February 2012.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Big Cedar Creek	6BBCD004.18	5/1994 - 3/2001	31	0	900	222	170	235	19.4
Clinch River	6BCLN271.50	1/2005 – 2/2012	38	25	2,000	222	120	366	5.3
Indian Creek	6BIDN000.69	8/2001 - 6/2003	12	100	2,600	608	400	727	50.0
Little River	6BLTR000.75	9/95 - 6/2003	37	0	1,400	183	100	253	10.8
Little River	6BLTR003.00	1/1990 - 3/1994	27	10	4,300	311	100	811	7.4
Little River	6BLTR018.19	8/2001 - 6/2003	12	100	2,200	400	150	612	16.7
Little River	6BLTR019.45	3/2008 - 5/2009	2	25	25	25	25	0	0.0
Little River	6BLTR025.03	4/2005	1	75	75	75	NA	NA	0.0
Lewis Creek	6BLWS000.06	8/2001 - 6/2003	11	100	2,100	427	100	629	18.2
Lewis Creek	6BLWS003.88	10/2001	1	100	100	100	NA	NA	0.0
Maiden Spring Creek	6BMSC001.53	8/2001 - 6/2003	8	100	1,000	300	100	374	25.0
Maiden Spring Creek	6BMSC008.98	8/2001 - 3/2007	13	25	8,000	1,463	100	2,834	38.5

NA – Not applicable
[1] Based on an instantaneous fecal coliform standard of 400 cfu/100mL.

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from August 2003 – February 2012.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Big Cedar Creek	6BBCD001.89	7/2003 - 12/2010	24	25	2,000	369	88	595	33.3
Big Cedar Creek	6BBCD006.66	7/2003 - 12/2010	24	25	2,000	352	200	530	33.3
Big Cedar Creek	6BBCD009.83	7/2003 - 12/2010	24	25	2,000	534	380	526	70.8
Burgess Creek	6BBUG000.10	1/2009 – 12/2010	12	75	2,000	735	615	675	66.7
Clinch River	6BCLN271.50	1/2005 – 2/2012	52	25	2,000	225	100	395	25.0
Dumps Creek	6BDUM000.04	1/2005 - 12/2010	16	25	320	76	50	85	12.5
Elk Garden Creek	6BEKG004.18	1/2005 - 12/2010	15	50	2,000	784	600	672	86.7
Elk Garden Creek	6BEKG008.48	1/2009 - 12/2010	12	100	2,000	600	300	675	75.0
Hess Creek	6BHES000.05	2/2007 – 4/2011	24	25	2,000	451	125	693	37.5
Indian Creek	6BIDN000.69	1/2007 - 1/2011	22	25	1,100	225	25	352	22.7
Little River	6BLTR000.75	1/2007 - 11/2008	11	25	750	114	25	216	9.1
Little River	6BLTR018.19	1/2007 - 1/2011	22	25	2,000	390	265	557	54.5
Little River	6BLTR019.45	3/2008 - 5/2009	2	20	20	20	NA	0	0.0
Little River	6BLTR025.03	4/2005	1	90	90	90	NA	NA	0.0
Little River	6BLTR025.45	1/2007 - 11/2008	12	25	400	97	63	105	8.3
Lewis Creek	6BLWS000.06	2/2007 - 1/2011	22	25	2,000	364	63	533	40.9
Lewis Creek	6BLWS004.84	2/2007 - 1/2011	21	25	1,600	263	75	392	33.3
Loop Creek	6BLOO004.25	1/2005 - 12/2010	15	25	1,300	339	220	396	46.7
Loop Creek	6BLOO006.03	1/2009 - 12/2010	12	25	2,000	441	265	546	50.0
Maiden Spring Creek	6BMSC001.53	1/2007 - 4/2010	5	25	950	225	50	406	20.0
Maiden Spring Creek	6BMSC008.98	1/2007 - 1/2011	21	25	2,000	345	120	571	38.1
Swords Creek	6BSWO000.11	4/2009 - 1/2011	21	25	1,800	386	150	501	38.1
Swords Creek	6BSWO001.81	2/2007 - 12/2008	12	25	1,400	289	98	448	25.0
Thompson Creek	6BTMP003.58	8/2003 - 12/2010	24	25	2,000	609	340	626	58.3
Weaver Creek	6BWEA000.02	8/2003 - 12/2010	24	25	2,000	643	350	677	58.3
Weaver Creek	6BWEA004.32	8/2003 - 12/2010	24	25	2,000	636	235	731	50.0

NA – Not applicable
[1] Based on the current instantaneous *E. coli* standard of 235 cfu/100mL.

3. BACTERIA SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal bacteria in the Middle Clinch River watershed study area. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in Appendix C.

3.1 Assessment of Permitted Sources

Four point sources are permitted to discharge to surface water bodies in the Middle Clinch River watershed study area through the Virginia Pollutant Discharge Elimination System (VPDES). These are listed in **Table 3.1**. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain an *E. coli* concentration below 126 cfu/100mL, the current standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard.

Table 3.2 shows the 45 single family home permits within the Middle Clinch River watershed study area. The use of “UT” in this table refers to Unnamed Tributaries. These permits allow treated residential wastewater to be discharged to surface waters. All of these housing units discharge water and bacteria to the streams.

There are no VPDES Animal Feeding Operations (AFOs) or Virginia Pollution Abatement (VPA) facilities in the study area.

Table 3.1 Summary of VPDES permitted point sources permitted for fecal bacteria control in the Middle Clinch River watershed study area.

Permit	Receiving Stream(s)	Facility Name	Permitted for *E. coli* Control
VA0020672	Casey Branch	DOC - Appalachian Detention Center 29	Y
VA0020745	Big Cedar Creek	Lebanon WWTP	Y
VA0026387	Lewis Creek	Honaker STP	Y
VA0064271	Little River	Claypool Hill STP	Y

Table 3.2 Single family home permits in the Middle Clinch River watershed study area.

Permit	Receiving Stream	Facility Type
VAG400175	Sugar Run, UT	Domestic
VAG400278	UT	Domestic
VAG400421	Right Fork Mill Creek	Domestic
VAG400434	Sulfur Spring UT	Domestic
VAG400444	Long Branch	Domestic
VAG400492	Long Branch Creek	Domestic
VAG400511	Sugar Run Creek	Domestic
VAG400513	Groundhog Hollow, UT	Domestic
VAG400521	Lewis Creek, UT	Domestic
VAG400587	Strow Creek	Domestic
VAG400614	Lewis Creek, UT	Domestic
VAG400622	Long Branch	Domestic
VAG400628	Pine Creek	Domestic
VAG400647	Long Branch	Domestic
VAG400811	Lewis Creek, UT	Domestic
VAG400835	Mill Creek	Domestic
VAG400900	Clinch River UT	Domestic
VAG400058	Indian Creek	Domestic
VAG400094	Katie Branch, UT	Domestic
VAG400114	Katie Branch	Domestic
VAG400177	Indian Creek	Domestic
VAG400279	Indian Creek	Domestic
VAG400542	Indian Creek, UT	Domestic
VAG400551	Indian Creek	Domestic
VAG400598	Indian Creek	Domestic
VAG400600	Indian Creek	Domestic
VAG400605	Katie Branch	Domestic
VAG400638	Indian Creek	Domestic
VAG400760	Katie Branch, UT	Domestic
VAG400832	Indian Creek, UT	Domestic
VAG400872	Maiden Spring Creek UT	Domestic
VAG400133	UT	Domestic
VAG400186	Willis Branch	Domestic
VAG400280	Elk Garden Creek	Domestic
VAG400411	Little Cedar Creek	Domestic
VAG400615	Roaring Spring Branch	Domestic
VAG400624	Roaring Spring Branch, UT	Domestic

Table 3.2 Single family home permits in the Middle Clinch River watershed study area (cont.).

Permit	Receiving Stream	Facility Type
VAG400754	Boardwine Branch, UT	Domestic
VAG400777	Mountain Branch	Domestic
VAG400844	Elk Garden Creek	Domestic
VAG400862	Elk Garden Creek UT	Domestic
VAG400866	Elk Garden Creek UT	Domestic
VAG400143	Clinch River	Domestic
VAG400692	Breezers Branch	Domestic
VAG400795	Clinch River, UT	Domestic

3.2 Assessment of Nonpoint Sources

In the Middle Clinch River watershed study area, both residential and agricultural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage disposal systems, land application of waste (livestock), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech previously collected samples of fecal coliform sources (*i.e.,* wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria. This analysis was used to support the modeling process for the current project and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.3.1.3). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Population, housing units, and type of sewage treatment from U.S. Census Bureau were calculated using GIS (**Table 3.3**). In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool, or the sewage is disposed of in some other way. The Census category "Other Means" includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via a straight pipe (direct stream outfall).

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity or the capacity is reduced by a blockage, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal bacteria is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal bacteria to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A survey of septic pump-out contractors, previously performed by MapTech, showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.3 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for areas contributing to impaired segments in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Human Population	Housing Units	Homes with Sewer	Homes with Septic	Estimated Homes with Straight Pipes
Big Cedar/Burgess	7,276	3,420	1,739	1,640	3
Elk Garden/Loop	2,025	912	9	890	1
Lewis Creek	2,577	1,364	502	810	4
Middle Clinch River	13,275	5,672	856	4,531	22
Swords/Hess	4,157	2,201	580	1,462	13
Dumps Creek	341	182	25	139	1
Total	**29,651**	**13,751**	**3,711**	**9,472**	**44**

3.2.2 Biosolids

Biosolids have not been applied in the Middle Clinch River watershed study area.

3.2.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the Middle Clinch River watershed study area watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured by MapTech. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech. A summary of the data collected is given in **Table 3.4**. **Table 3.5** lists the domestic animal populations for impairments in the Middle Clinch River watershed study area.

Table 3.4 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.5 Estimated domestic animal populations in areas contributing to impaired segments in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Dogs	Cats
Big Cedar/Burgess	1,724	1,930
Elk Garden/Loop	451	505
Lewis Creek	676	757
Middle Clinch River	2,792	3,125
Swords Creek	1,090	1,220
Dumps Creek	83	92
Total	**6,816**	**7,629**

3.2.4 Livestock

The predominant type of livestock in the Middle Clinch River watershed study area is beef cattle, although other types of livestock identified were considered in modeling the watershed. **Table 3.6** gives a summary of livestock populations in the Middle Clinch River watershed study area. Animal populations were based on communication with VADEQ, Clinch Valley Soil and Water Conservation District (CVSWCD), Tazewell Soil and Water Conservation District (TSWCD), watershed visits, and verbal communication with citizens at the first public meeting.

Table 3.6 Livestock populations in areas contributing to impaired segments in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Beef	Beef Calves	Dairy	Dairy Calves	Dairy (Dry)	Horse	Sheep
Big Cedar/Burgess	2,840	1,420	47	24	24	379	331
Elk Garden/Loop	1,802	901	30	15	15	240	210
Lewis Creek	10,004	5,002	167	83	83	1,334	1,167
Middle Clinch River	16,908	8,453	693	345	345	2,680	3,327
Swords Creek	14,723	7,362	245	123	123	1,963	1,718
Dumps Creek	888	444	15	7	7	118	104
Total	**47,165**	**23,582**	**1,197**	**597**	**597**	**6,714**	**6,857**

Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999a). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in **Table 3.7**.

Table 3.7 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Dairy milker (1,400 lb)	120.4	271,329	0.5
Dairy heifer (850 lb)	70.0	271,329	0.25
Dairy calf (350 lb)	29.0	271,329	0.5
Hog (135 lb)	11.3	400,000	0.8
Horse (1,000 lb)	51.0	94,000	NA
Sheep (60 lb)	2.4	43,000	NA

[1]units are cfu/100ml

Fecal bacteria produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.,* pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Dairy cows were considered confined at all times, and therefore dairy waste was modeled as being collected and applied throughout the year. **Table 3.8** shows the average percentage of collected dairy waste that is applied throughout the year. Second, grazing livestock deposit manure directly on the land where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities may have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Table 3.8 Average percentage of collected dairy waste applied throughout year.

	Applied % of Total	
Month	**Dairy**	**Land use**
January	1.50	Cropland
February	1.75	Cropland
March	17.00	Cropland
April	17.00	Cropland
May	17.00	Cropland
June	1.75	Pasture
July	1.75	Pasture
August	1.75	Pasture
September	5.00	Cropland
October	17.00	Cropland
November	17.00	Cropland
December	1.50	Cropland

Some livestock were expected to deposit a portion of waste on land areas. The percentage of time spent on pasture for livestock was estimated based on projects in other areas of southwest Virginia. All livestock, with the exception of actively milked dairy cows, were assumed to be in pasture 100% of the time.

It was assumed that beef cattle were expected to make a significant contribution through direct deposition with access to flowing water. For areas where direct deposition by cattle is assumed, the average amount of time that beef cattle, dry cows, and replacement heifers spend in stream access areas for each month is given in **Table 3.9**.

Table 3.9 Average time beef cows, dry cows, and replacement heifers spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	23.0	1.0	0
April	22.6	1.4	0
May	22.6	1.4	0
June	22.3	1.7	0
July	22.3	1.7	0
August	22.3	1.7	0
September	22.6	1.4	0
October	23.0	1.0	0
November	23.0	1.0	0
December	23.3	0.7	0

3.2.5 Wildlife

The predominant wildlife species in the Middle Clinch River watershed study area were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, and source sampling. Population densities were calculated from data provided by VDGIF and FWS, and are listed in Table 3.10 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987).

Table 3.10 Wildlife population densities for the Middle Clinch River watershed study area.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)
0.0279	0.0087	0.0189	0.0333	0.6115	0.0226	0.25

The numbers of animals estimated to be in the Middle Clinch River watershed study area are reported in **Table 3.11**. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF

(Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b).

Table 3.11 Estimated wildlife populations in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Deer	Duck	Goose	Raccoon	Turkey	Muskrat	Beaver
Big Cedar/Burgess	1,115	69	34	2,288	263	3,330	566
Elk Garden/Loop	865	51	25	1,773	220	2,460	504
Lewis Creek	481	24	12	985	114	1,139	235
Middle Clinch River	5,103	215	105	10,474	1,275	10,308	2,035
Swords Creek	979	51	25	2,020	233	2,427	494
Dumps Creek	670	33	16	1,430	165	1,567	302
Total	**9,213**	**443**	**217**	**18,970**	**2,270**	**21,231**	**4,136**

Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in **Table 3.12**.

Table 3.12 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

Table 3.13 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife scat performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver.

Table 3.13 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	**Primary** = region within 600 ft of perennial streams **Secondary** = region between 601 and 7,920 ft from perennial streams **Infrequent/Seldom** = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Beaver[1]	200	**Primary** = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) **Infrequent/Seldom** = rest of the watershed area
Deer	772	**Primary** = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land **Secondary** = low density residential, medium density residential **Infrequent/Seldom** = remaining land use areas
Turkey[2]	320	**Primary** = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land **Secondary** = cropland, pasture **Infrequent/Seldom** = remaining land use areas
Goose[3]	225	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Mallard (Duck)	150	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area

[1] Beaver waste load was calculated as twice that of muskrat, based on field observations.
[2] Waste load for domestic turkey (ASAE, 1998).
[3] Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003)

4. BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Computer modeling is used in this study as a tool that allows simulating the interaction between the land surface and subsurface and the quantities of various bacteria sources by location. The model allows the climatological factors and in particular, precipitation, to drive this interaction. By modeling the watershed conditions and bacteria sources, the model allows quantifying the relationship between sources as they exist throughout the watershed to bacteria concentrations within the watershed. The model used in the analysis was the USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources.

Flow was calibrated by comparing model output to observed flow within the Middle Clinch River and making the proper adjustments to obtain the best match between simulated and observed flow. Once the flow component was built, the bacteria concentration was calibrated by comparing model simulations of bacteria to observed bacteria values collected by VADEQ at two locations. Finally the bacteria concentration was validated using a different time period from the calibration period.

Bacteria loadings from various sources are simulated including point sources, runoff from the watershed, interflow and groundwater. A complete description of the modeling approach is presented in Appendix C.

5. BACTERIAL ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, non-permitted sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g*., accuracy of wildlife populations). The definition is typically denoted by the expression:

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For these impairments, the TMDLs are expressed in terms of colony forming units (or resulting concentration).

Allocation scenarios were modeled using the HSPF model. Scenarios were created by reducing direct and land-based bacteria until the water quality standards were attained. The TMDLs developed for the impairments in the Middle Clinch River watershed study area were based on the *E. coli* riverine Virginia State standards. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml.

According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling bacteria with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc})$$

where C_{ec} is the concentration of *E. coli* in cfu/100 mL and C_{fc} is the concentration of fecal coliform in cfu/100 mL.

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standards were met. The Upper Clinch River watershed (subwatershed 6) was set to its allocated load for the modeling runs because it has a previously approved bacteria TMDL. The development of the allocation scenarios was an iterative process that required numerous runs with each followed by an assessment of source reduction against the applicable water quality standards.

5.1 Margin of Safety (MOS)

In order to account for uncertainty in modeled output, a Margin of Safety (MOS) was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of a bacteria TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of these TMDLs. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of these TMDLs are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration, and
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed.

5.2 Waste Load Allocations (WLAs)

There are 49 point sources currently permitted to discharge into the Middle Clinch River watershed study area. The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). Future growth in each watershed was accounted for by setting aside 1% of the TMDL for growth in permitted discharges or creation of new ones. There are currently no Municipal Separate Storm Sewer System (MS4) permits in the Middle Clinch River watershed study area.

5.3 Load Allocations (LAs)

Load allocations to nonpoint sources are divided into land-based loadings from land uses (nonpoint source, NPS) and directly applied loads in the stream (livestock, wildlife, straight pipes, and sewer overflows). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads most significantly impact bacteria concentrations during high-flow conditions, while direct deposition NPS most significantly impact low flow bacteria concentrations. Nonpoint source load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use. Appendix B shows tables of the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds to each impairment.

5.4 Final Total Maximum Daily Loads (TMDLs)

Allocation scenarios were run sequentially, beginning with headwater impairments, and then continuing with downstream impairments until all impairments were allocated to 0% exceedances of all applicable standards. The first table in each of the following sections represents the scenarios developed to determine the TMDLs. The first scenario was run for all impairments simultaneously; subsequent runs were made after upstream impairments were allocated. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, a scenario reflects the impact of eliminating direct human sources from straight pipes and sewer overflows. Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet 0% exceedance of all applicable water quality standards. The graphs in the following sections depict the existing and allocated 30-day geometric mean in-stream bacteria concentrations.

The second table in each of the following sections shows the existing and allocated *E. coli* loads that are output from the HSPF model. The third table shows the final in-stream allocated loads for the appropriate bacteria species. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. The final table is an estimation of the in-stream daily load of bacteria.

The tables and graphs in the following sections all depict values at the corresponding impairment outlet or the most limiting subwatershed. The tables and graphs in the following sections all depict values at the most limiting subwatershed for each Nested TMDL Unit.

5.4.1.1 Middle Clinch River Modeling Group

Table 5.1 shows allocation scenarios used to determine the final TMDL for the Middle Clinch River watershed impairments (VAS-P07R_CLN01A00, VAS-P05R_IDN01A04, VAS-P07R_WEA01A06, VAS-P07R_TMP01A06, VAS-P05R_LTR02A00, VAS-P05R_LTR02A02, VAS-P05R_MSC01A02, and VAS-P05R_MSC01C04). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 31.43% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenario 4 is an intermediate scenario. Scenario 5 requires an 8% reduction to residential sources and eliminating straight pipes and direct inputs from livestock. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 4 will be the target goal during the implementation of best management practices (BMPs).

Table 5.1 Allocation scenarios for reducing current bacteria loads in the Middle Clinch River Modeling Group

	Percent Reductions to Existing Bacteria Loads						
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	**Wildlife Direct**	**Barren[1], Forest, Gas well, Reclaimed Mine[2]**	**Livestock Direct**	**Cropland, Pasture, LAX[3]**	**Straight Pipes**	**Developed, Commercial**	**% >126 GM**
1	0	0	0	0	0	0	31.43%
2	0	0	0	0	100	0	26.12%
3	0	0	100	0	100	0	14.29%
4	0	0	100	0	100	5	2.86%
5[4]	0	0	100	0	100	8	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Middle Clinch River modeling group (subwatershed 8). Subwatershed 8 is shown because it was the most limiting subwatershed out of this modeling group. The graph shows existing conditions in black, with allocated conditions overlaid in blue.

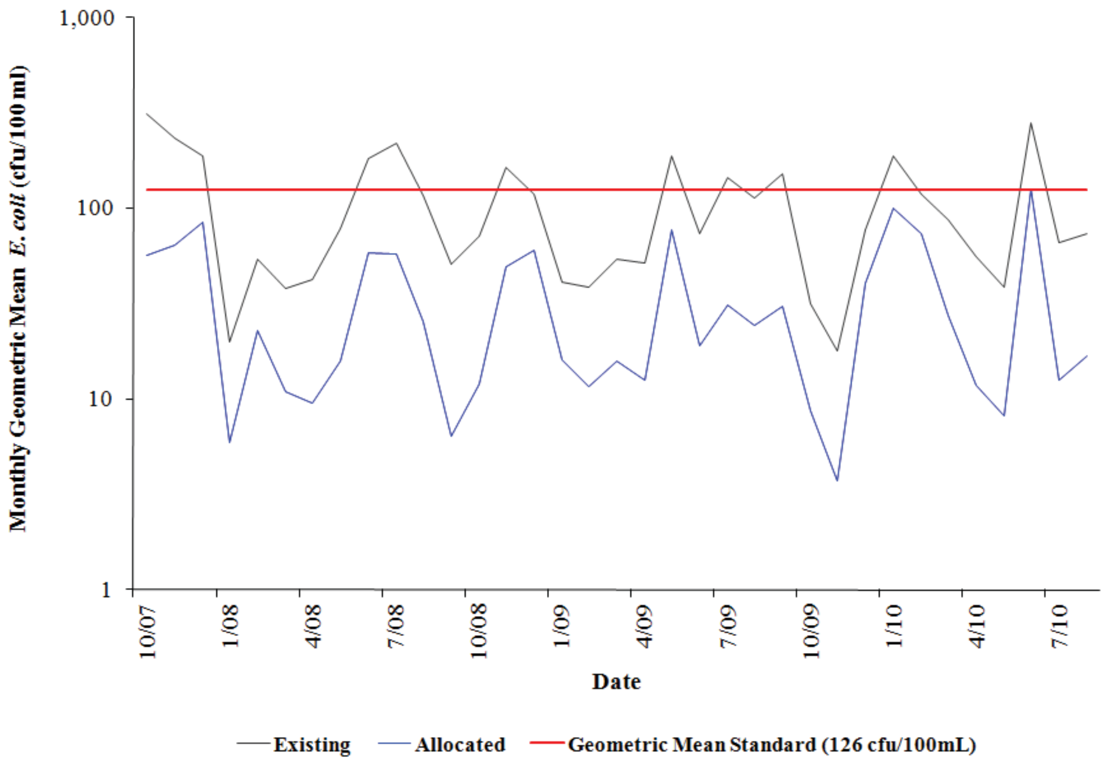

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Middle Clinch River Modeling Group

Table 5.2 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.2 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Middle Clinch River Modeling Group

Impairment	WLA	LA	MOS	TMDL
Clinch River	**1.60E+13**	**1.51E+15**	*Implicit*	**1.53E+15**
VA0020672	*2.09E+10*			
VA0064271	*6.55E+11*			
VAG400143	*1.74E+09*			
VAG400795	*1.74E+09*			
VAG400094	*1.74E+09*			
VAG400114	*1.74E+09*			
VAG400605	*1.74E+09*			
VAG400760	*1.74E+09*			
VAG400872	*1.74E+09*			
VAG400058	*1.74E+09*			
VAG400279	*1.74E+09*			
VAG400542	*1.74E+09*			
VAG400551	*1.74E+09*			
VAG400598	*1.74E+09*			
VAG400600	*1.74E+09*			
VAG400638	*1.74E+09*			
VAG400832	*1.74E+09*			
VAG400692	*1.74E+09*			
Future Load	*1.53E+13*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.3. The daily TMDL was calculated using the 99th

percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.3 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Middle Clinch River Modeling Group

Impairment	WLA	LA	MOS	TMDL
Clinch River	**4.38E+10**	**2.24E+13**	*Implicit*	**2.25E+13**
VA0020672	*5.73E+07*			
VA0064271	*1.79E+09*			
VAG400143	*4.77E+06*			
VAG400795	*4.77E+06*			
VAG400094	*4.77E+06*			
VAG400114	*4.77E+06*			
VAG400605	*4.77E+06*			
VAG400760	*4.77E+06*			
VAG400872	*4.77E+06*			
VAG400058	*4.77E+06*			
VAG400279	*4.77E+06*			
VAG400542	*4.77E+06*			
VAG400551	*4.77E+06*			
VAG400598	*4.77E+06*			
VAG400600	*4.77E+06*			
VAG400638	*4.77E+06*			
VAG400832	*4.77E+06*			
VAG400692	*4.77E+06*			
Future Load	*4.18E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.2 Big Cedar/Burgess Creek Modeling Group

Table 5.4 shows allocation scenarios used to determine the final TMDL for the Big Cedar/Burgess Creek Modeling Group impairments (VAS-P06R_BCD01A98, VAS-P06R_BCD02A02, VAS-P06R_BCD02A00, P06R_BCD03A00, and VAS-P06R_BUG01A06). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 65.71% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 86% reduction to agricultural land based loads, and a 90% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

Table 5.4 Allocation scenarios for reducing current bacteria loads in the Big Cedar/Burgess Creek Modeling Group.

Percent Reductions to Existing Bacteria Loads							
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren[1], Forest, Gas well, Reclaimed Mine[2]	Livestock Direct	Cropland, Pasture, LAX[3]	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	65.71%
2	0	0	0	0	100	0	57.92%
3	0	0	100	0	100	0	42.86%
4	0	0	100	50	100	50	25.71%
5	0	0	100	75	100	75	14.29%
6[4]	0	0	100	86	100	90	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.2 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Big Cedar/Burgess Creek Modeling Group (subwatershed 9). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

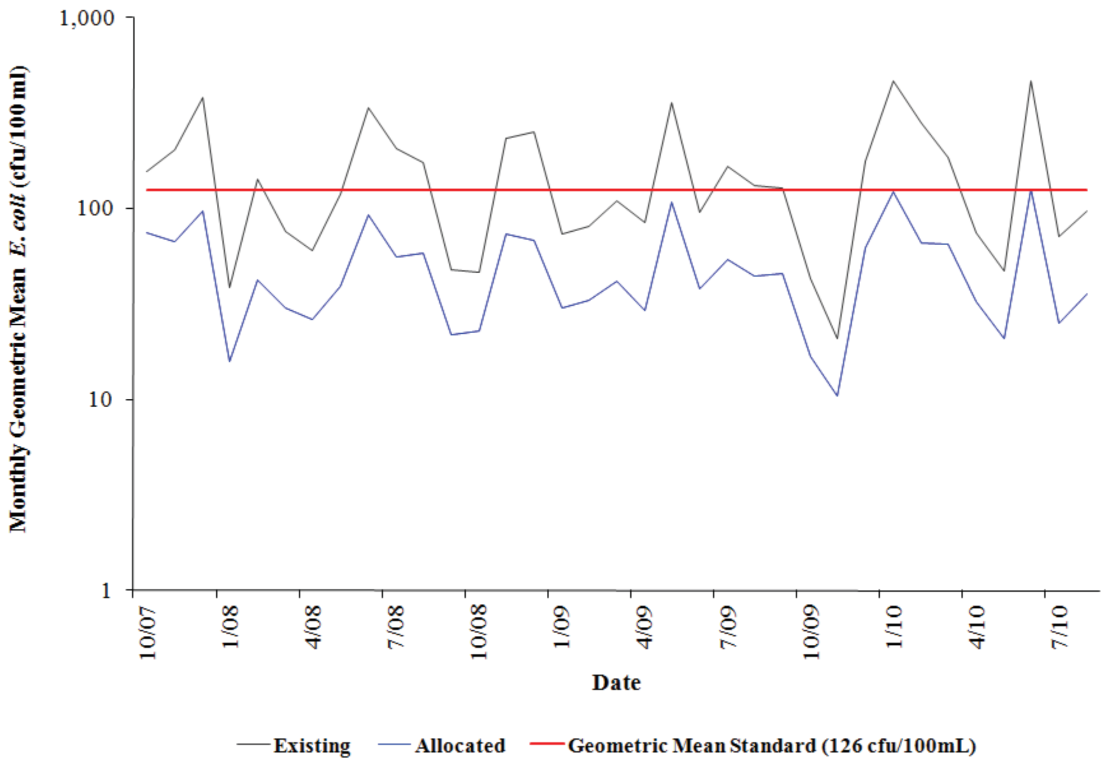

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Big Cedar/Burgess Creek Modeling Group

Table 5.5 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.5 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Big Cedar/Burgess	**1.34E+13**	**1.17E+15**	*Implicit*	**1.18E+15**
VA0020745	*1.50E+12*			
VAG400133	*1.74E+09*			
VAG400186	*1.74E+09*			
VAG400411	*1.74E+09*			
VAG400615	*1.74E+09*			
VAG400624	*1.74E+09*			
VAG400777	*1.74E+09*			
Future Load	*1.18E+13*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.6. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.6 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Big Cedar/Burgess	**3.66E+10**	**4.23E+12**	*Implicit*	**4.26E+12**
VA0020745	*4.12E+09*			
VAG400133	*4.77E+06*			
VAG400186	*4.77E+06*			
VAG400411	*4.77E+06*			
VAG400615	*4.77E+06*			

VAG400624	*4.77E+06*
VAG400777	*4.77E+06*
Future Load	*3.24E+10*

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.3 Elk Garden/Loop Creek Modeling Group

Table 5.7 shows allocation scenarios used to determine the final TMDL for the Elk Garden/Loop Creek Modeling Group impairments (VAS-P06R_LOO01A06, and VAS-P06R_EKG01A06). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 82.86% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 83% reduction to agricultural land based loads, and a 89% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

Table 5.7 Allocation scenarios for reducing current bacteria loads in the Elk Garden/Loop Creek Modeling Group.

	Percent Reductions to Existing Bacteria Loads						
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren[1], Forest, Gas well, Reclaimed Mine[2]	Livestock Direct	Cropland, Pasture, LAX[3]	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	48.57%
2	0	0	0	0	100	0	42.37%
3	0	0	100	0	100	0	34.29%
4	0	0	100	50	100	50	17.14%
5	0	0	100	75	100	75	11.43%
6[4]	0	0	100	83	100	89	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.3 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Elk Garden/Loop Creek modeling group (subwatershed 10). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

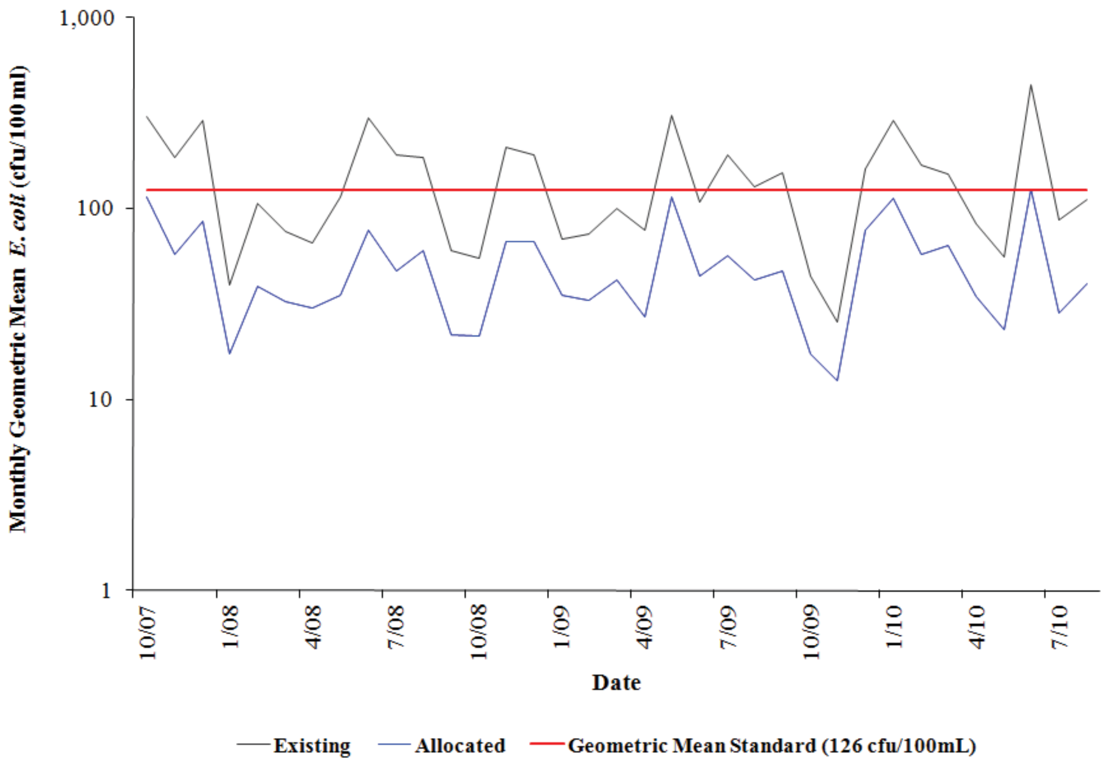

Figure 5.3 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Elk Garden/Loop Creek Modeling Group

Table 5.8 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.8 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Elk Garden/Loop	**6.36E+12**	**6.29E+14**	*Implicit*	**6.35E+14**
VAG400280	*1.74E+09*			
VAG400754	*1.74E+09*			
VAG400844	*1.74E+09*			
VAG400862	*1.74E+09*			
VAG400866	*1.74E+09*			
Future Load	*6.35E+12*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.9. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.9 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Elk Garden/Loop	**1.74E+10**	**1.83E+12**	*Implicit*	**1.84E+12**
VAG400280	*4.77E+06*			
VAG400754	*4.77E+06*			
VAG400844	*4.77E+06*			
VAG400862	*4.77E+06*			
VAG400866	*4.77E+06*			
Future Load	*1.74E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.4 Lewis Creek Modeling Group

Table 5.10 shows allocation scenarios used to determine the final TMDL for the Lewis Creek Modeling Group impairments (VAS-P04R_LWS01A98 and VAS-P04R_LWS01A10). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 48.57% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 79% reduction to agricultural land based loads, and a 83% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

Table 5.20 Allocation scenarios for reducing current bacteria loads in the Lewis Creek Modeling Group.

	Percent Reductions to Existing Bacteria Loads							
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren[1], Forest, Gas well, Reclaimed Mine[2]	Livestock Direct	Cropland, Pasture, LAX[3]	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	48.57%
2	0	0	0	0	100	0	44.38%
3	0	0	100	0	100	0	31.43%
4	0	0	100	50	100	50	27.71%
5	0	0	100	75	100	75	14.29%
6[4]	0	0	100	79	100	83	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.4 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Lewis Creek modeling group (subwatershed 16). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

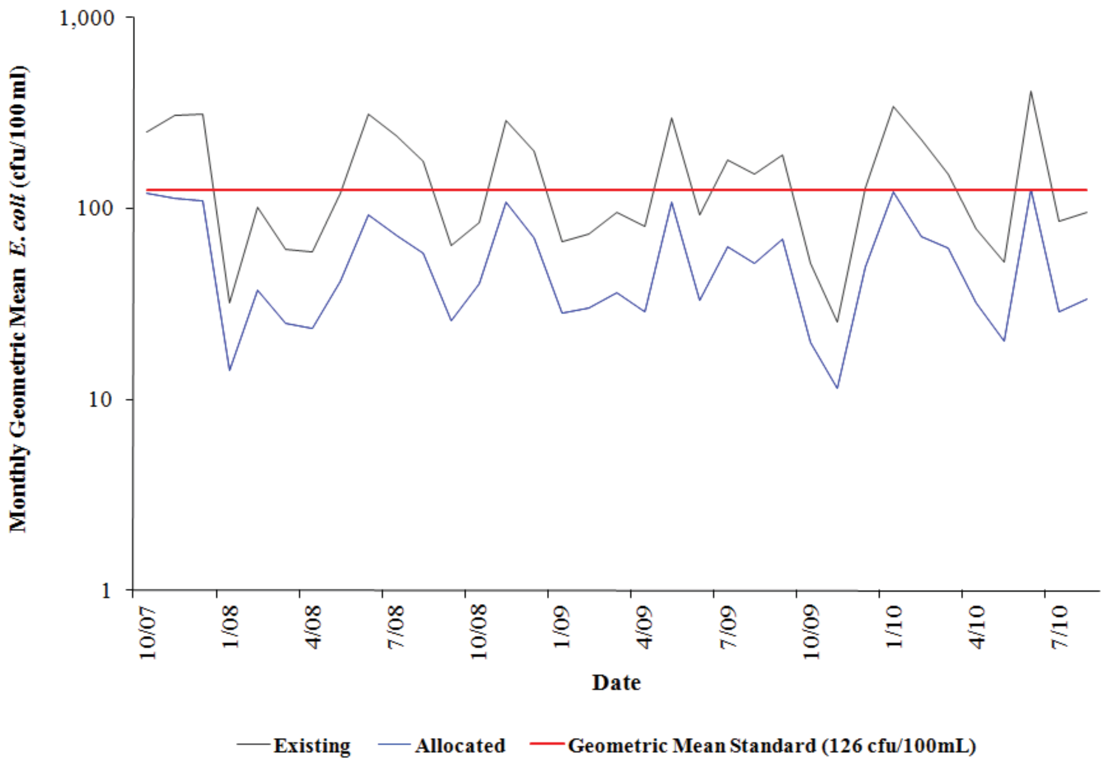

Figure 5.4 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Lewis Creek Modeling Group

Table 5.11 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.11 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Lewis Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Lewis Creek	**1.53E+13**	**4.88E+14**	*Implicit*	**5.03E+14**
VA0026387	*2.54E+12*			
VAG400521	*1.74E+09*			
VAG400614	*1.74E+09*			
VAG400811	*1.74E+09*			
Future Load	*1.27E+13*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.12. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.12 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Lewis Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Lewis Creek	**4.18E+10**	**1.22E+12**	*Implicit*	**1.26E+12**
VA0026387	*6.97E+09*			
VAG400521	*4.77E+06*			
VAG400614	*4.77E+06*			
VAG400811	*4.77E+06*			
Future Load	*3.48E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.5 Swords/Hess Creek Modeling Group

Table 5.13 shows allocation scenarios used to determine the final TMDL for the Swords/Hess Creek Modeling Group impairments (VAS-P04R_HES01A10 and VAS-P04R_SWD01A00). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 31.43% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, and a 63% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

Table 5.33 Allocation scenarios for reducing current bacteria loads in the Swords/Hess Creek Modeling Group.

Percent Reductions to Existing Bacteria Loads							
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren[1], Forest, Gas well, Reclaimed Mine[2]	Livestock Direct	Cropland, Pasture, LAX[3]	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	31.43%
2	0	0	0	0	100	0	27.38%
3	0	0	100	0	100	0	17.14%
4	0	0	100	50	100	50	2.86%
5	0	0	100	60	100	60	2.86%
6[4]	0	0	100	0	100	63	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.5 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Swords/Hess Creek modeling group (subwatershed 17). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

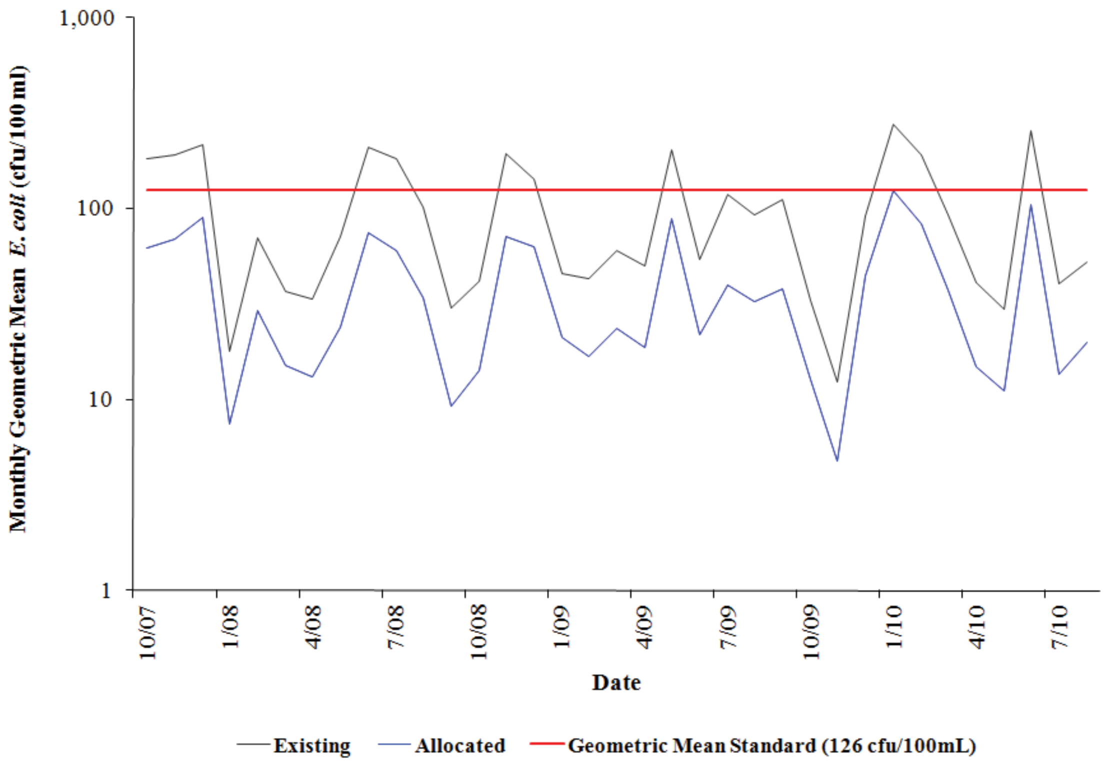

Figure 5.5 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Swords/Hess Creek Modeling Group

Table 5.14 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.14 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Swords/Hess Creek	**7.03E+12**	**6.94E+14**	*Implicit*	**7.01E+14**
VAG400175	*1.74E+09*			
VAG400421	*1.74E+09*			
VAG400492	*1.74E+09*			
VAG400511	*1.74E+09*			
VAG400622	*1.74E+09*			
VAG400647	*1.74E+09*			
VAG400835	*1.74E+09*			
VAG400278	*1.74E+09*			
VAG400434	*1.74E+09*			
VAG400444	*1.74E+09*			
VAG400513	*1.74E+09*			
VAG400587	*1.74E+09*			
VAG400628	*1.74E+09*			
Future Load	*7.01E+12*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.15. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.15 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
			Implicit	

Swords/Hess Creek	**1.93E+10**	**1.30E+12**		**1.32E+12**
VAG400175	*4.77E+06*			
VAG400421	*4.77E+06*			
VAG400492	*4.77E+06*			
VAG400511	*4.77E+06*			
VAG400622	*4.77E+06*			
VAG400647	*4.77E+06*			
VAG400835	*4.77E+06*			
VAG400278	*4.77E+06*			
VAG400434	*4.77E+06*			
VAG400444	*4.77E+06*			
VAG400513	*4.77E+06*			
VAG400587	*4.77E+06*			
VAG400628	*4.77E+06*			
Future Load	*1.92E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.6 Dumps Creek Modeling Group

Table 5.16 shows allocation scenarios used to determine the final TMDL for the Dumps Creek Modeling Group impairment (VAS-P08R_DUM01A94). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 17.14% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, and a 60%

reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

Table 5.46 Allocation scenarios for reducing current bacteria loads in the Dumps Creek Modeling Group.

	Percent Reductions to Existing Bacteria Loads							
	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren[1], Forest, Gas well, Reclaimed Mine[2]	Livestock Direct	Cropland, Pasture, LAX[3]	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	17.14%
2	0	0	0	0	100	0	14.38%
3	0	0	100	0	100	0	8.57%
4	0	0	100	25	100	25	5.71%
5	0	0	100	50	100	50	2.86%
6[4]	0	0	100	0	100	60	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.6 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Dumps Creek modeling group (subwatershed 7). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

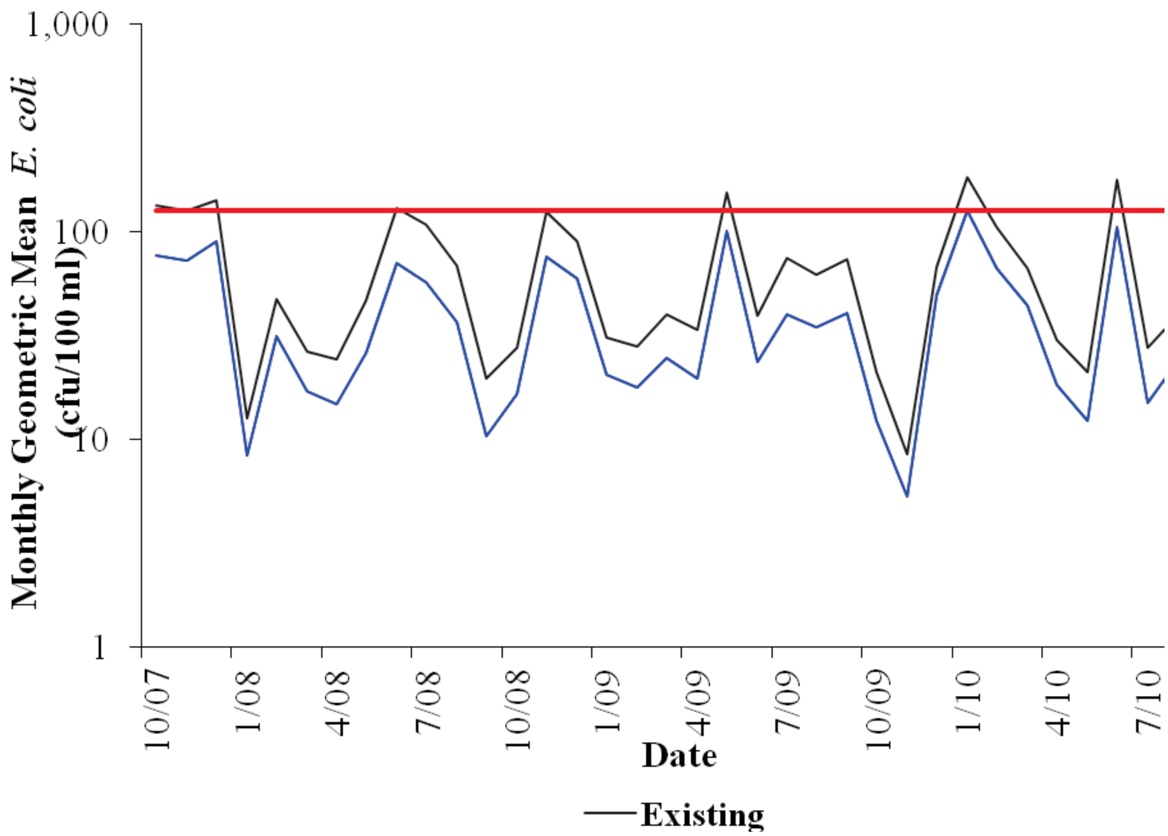

Figure 5.6 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Dumps Creek Modeling Group

Table 5.17 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.17 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Dumps Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Dumps Creek	**9.90E+12**	**9.80E+14**	*Implicit*	**9.90E+14**
Future Load	*9.90E+12*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.18. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.18 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Dumps Creek Modeling Group

Impairment	WLA	LA	MOS	TMDL
Dumps Creek	**2.71E+10**	**1.78E+12**	*Implicit*	**1.81E+12**
Future Load	*2.71E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

6. IMPLEMENTATION

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. EPA requires that there is reasonable assurance that TMDLs can be implemented. TMDLs represent an attempt to quantify the pollutant load that might be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Commonwealth intends to use existing programs in order to attain water quality goals.

The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

6.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ web site under http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/Regulation.aspx.

6.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

6.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

6.3.1 Stormwater

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented. More information regarding these programs can be found at http://www.dcr.virginia.gov/stormwater_management/index.shtml.

6.3.2 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/Programs/Water/LawsRegulationsGuidance/Guidance/TMDLGuidance.aspx.

6.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

6.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003. It is available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlanGuidanceManual.aspx.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.4.2 Staged Implementation Scenarios

6.4.2.1 Bacteria

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient bacterial BMPs for both urban and rural watersheds are stream side fencing for cattle farms, pet waste clean-up programs, and government or grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis (UAA) may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and by implementing cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 6.6.

Stage I scenarios are discussed in Chapter 5. Correcting 50% of straight pipes and sewer overflows will benefit the water quality significantly for all the impairments.

6.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality downstream in the Middle Clinch River watershed.

6.4.4 Implementation Funding Sources

The implementation of pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/Programs/Water/CleanWaterFinancingAssistance/WaterQualityImprovementFund.aspx and at http://www.dcr.virginia.gov/stormwater_management/wqia.shtml.

6.5 Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with *DEQ Guidance Memo No. 03-2004* (http://www.deq.virginia.gov/Programs/Water/LawsRegulationsGuidance/Guidance/TMDLGuidance.aspx), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. The details of the follow-up ambient monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office.

The objective of the Statewide Fish Tissue and Sediment Monitoring Program is to systematically assess and evaluate, using a multi-tier screening, waterbodies in Virginia in order to identify toxic contaminant(s) accumulation with the potential to adversely affect human users of the resource. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plans. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or to monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on VADEQ's citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years.

6.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;
5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or
6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment. Additional information can be obtained at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityStandards/DesignatedUses.aspx.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation is that all controllable sources would be reduced to the maximum extent possible using the implementation approaches described above. VADEQ will continue to monitor water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed".

7. PUBLIC PARTICIPATION

Public participation during TMDL development for the Middle Clinch River watershed was encouraged; a summary of the meetings is presented in **Table 7.1**. The first public meeting took place on May 26, 2011 at the Lebanon Town Hall in Lebanon, Virginia. ___ people attended the meeting. The second public meeting was held on May 24, 2012 and ___ people attended. The meetings were publicized by placing notices in the Virginia Register, signs in the watershed, and emailing notices to local stakeholders and representatives.

Table 7.1 Public participation during TMDL development for the Upper Clinch River watershed.

Date	Location	Attendance[1]	Type
5/26/2011	Lebanon Town Hall Lebanon, VA		1st public
5/24/2012	Lebanon Town Hall Lebanon, VA		2nd public

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

Public participation during the implementation plan development process will include the formation of stakeholders' committees, with committee and public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. Stakeholder committees will have the express purpose of formulating the TMDL Implementation Plan. The committees will consist of, but not be limited to, representatives from VADEQ, VADCR and local governments. These committees will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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APPENDIX A

Frequency Analysis of Bacteria Data

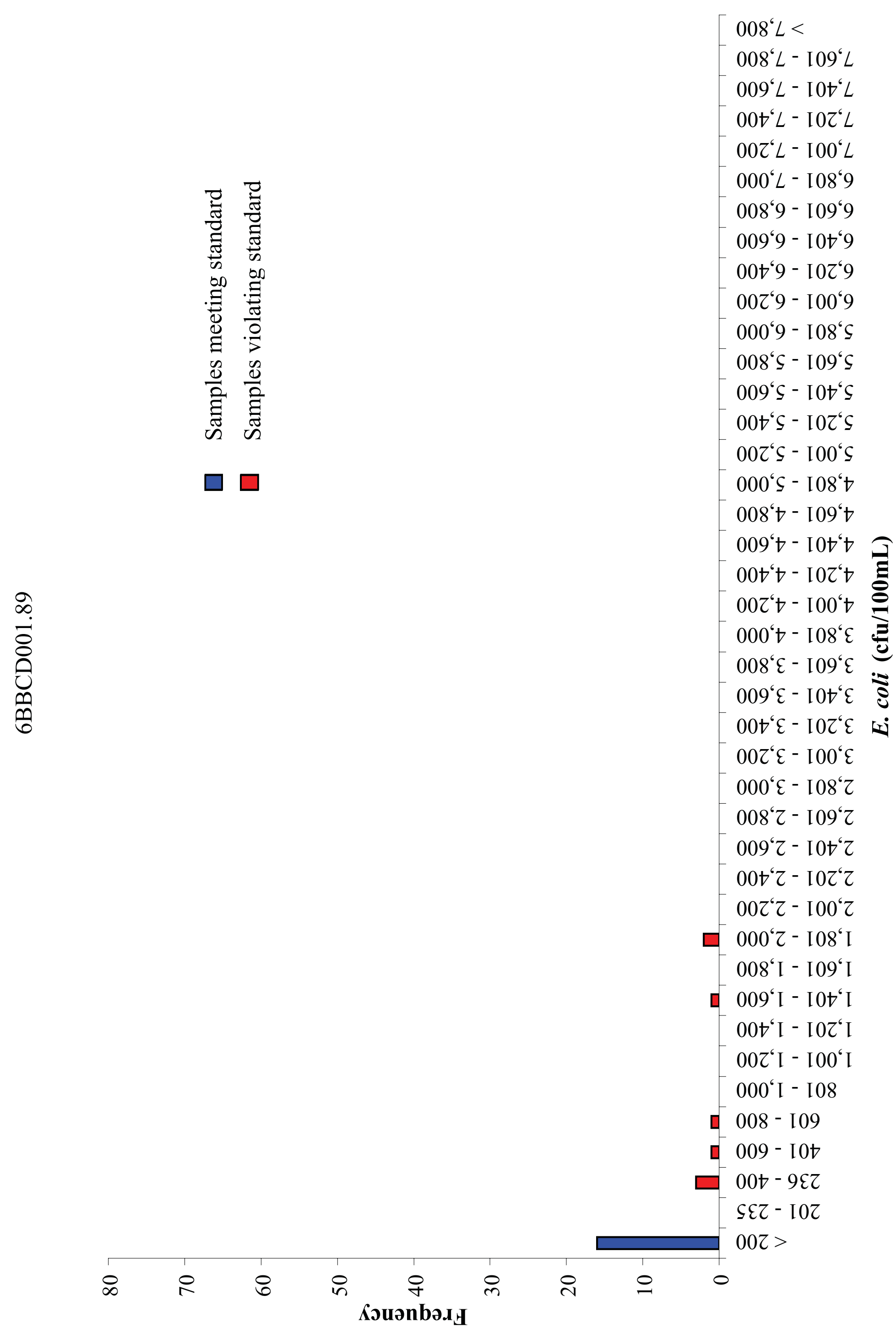

Figure A. 1 Frequency analysis of *E. coli* concentrations at station 6BBCD001.89 in Big Cedar Creek for the period from July 2003 to December 2010.

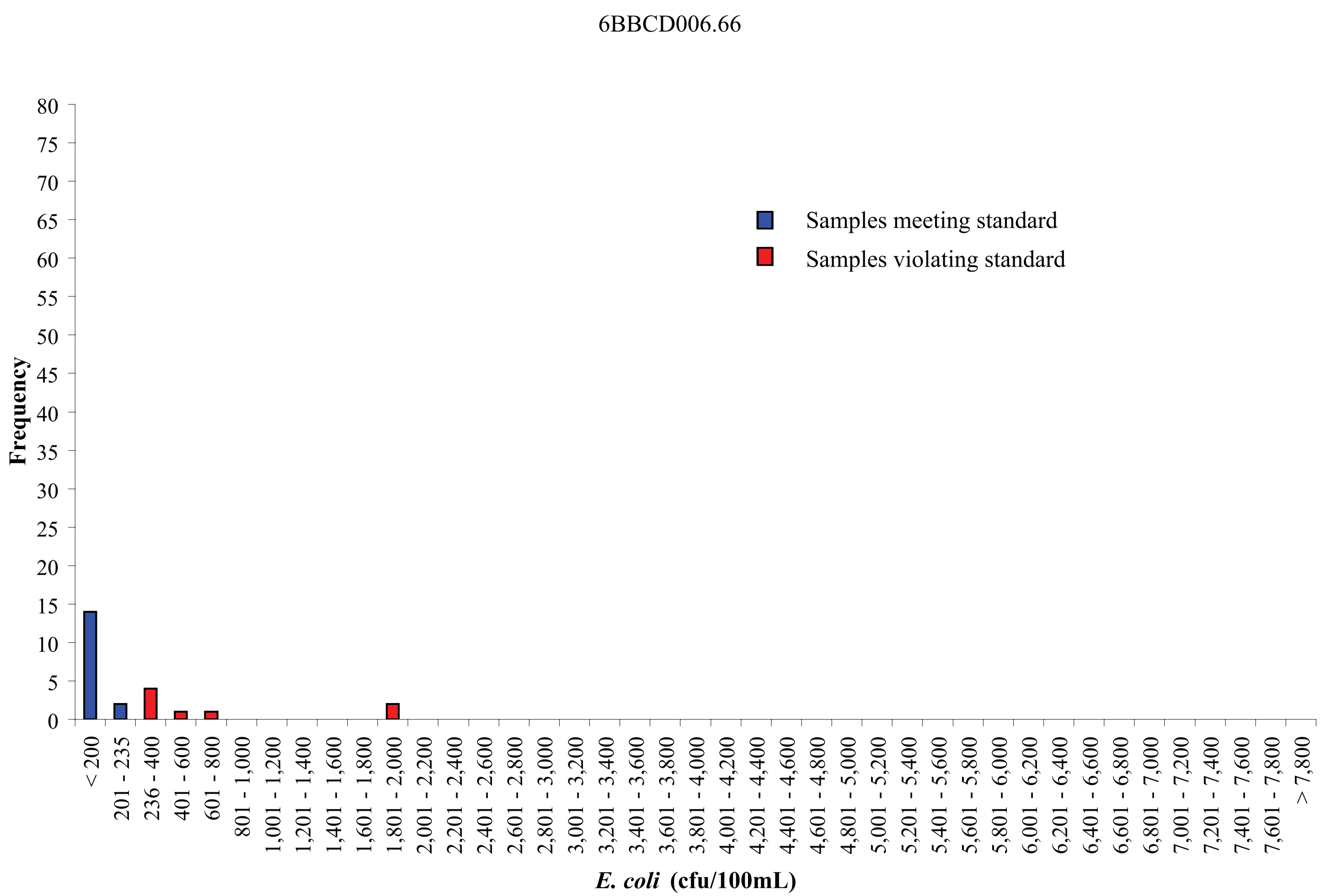

Figure A. 2 Frequency analysis of *E. coli* concentrations at station 6BBCD006.66 in Big Cedar Creek for the period from July 2003 to December 2010.

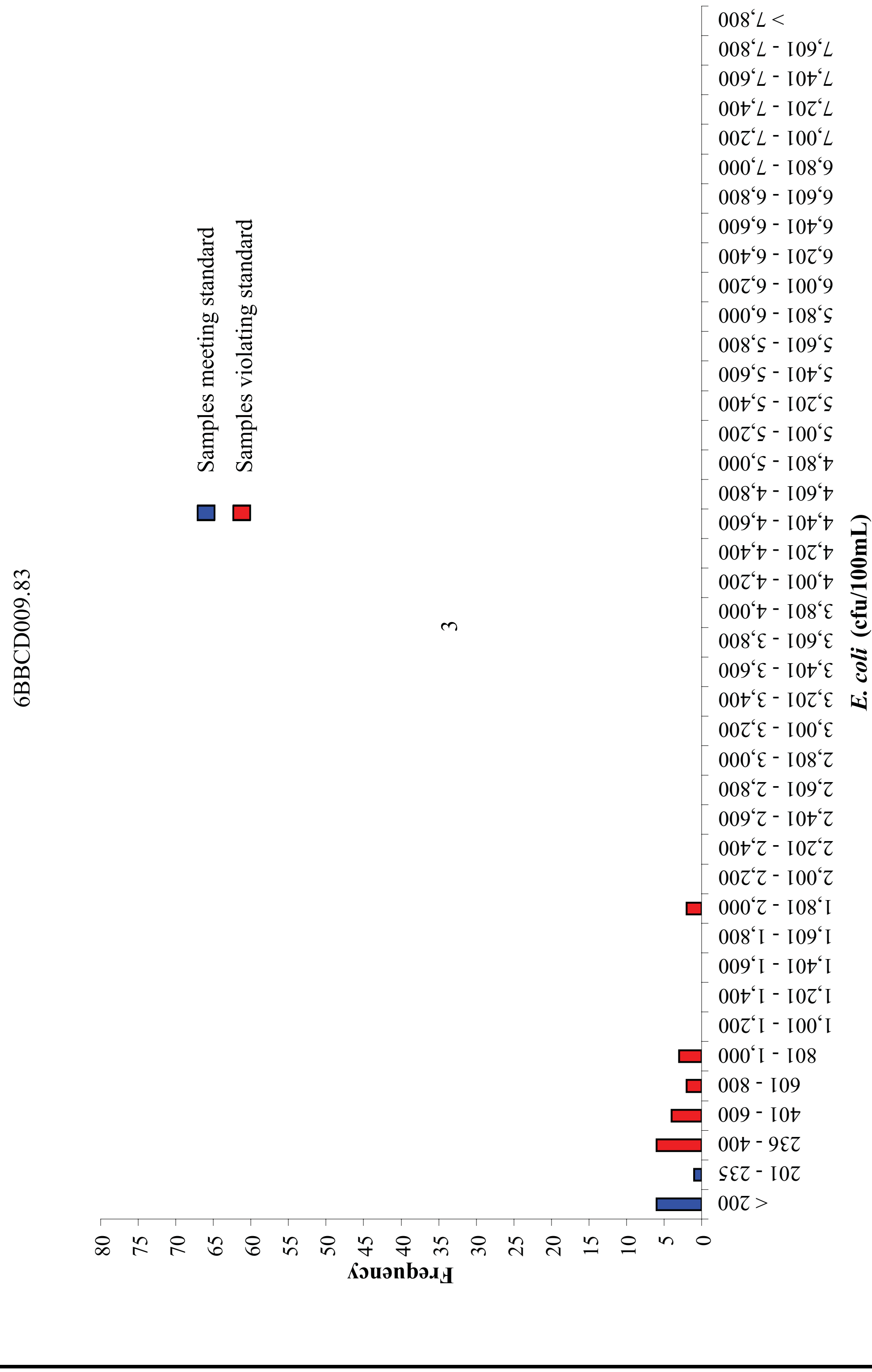

Figure A. 3 Frequency analysis of *E. coli* concentrations at station 6BBCD009.83 in the Big Cedar Creek for the period from July 2003 to December 2010.

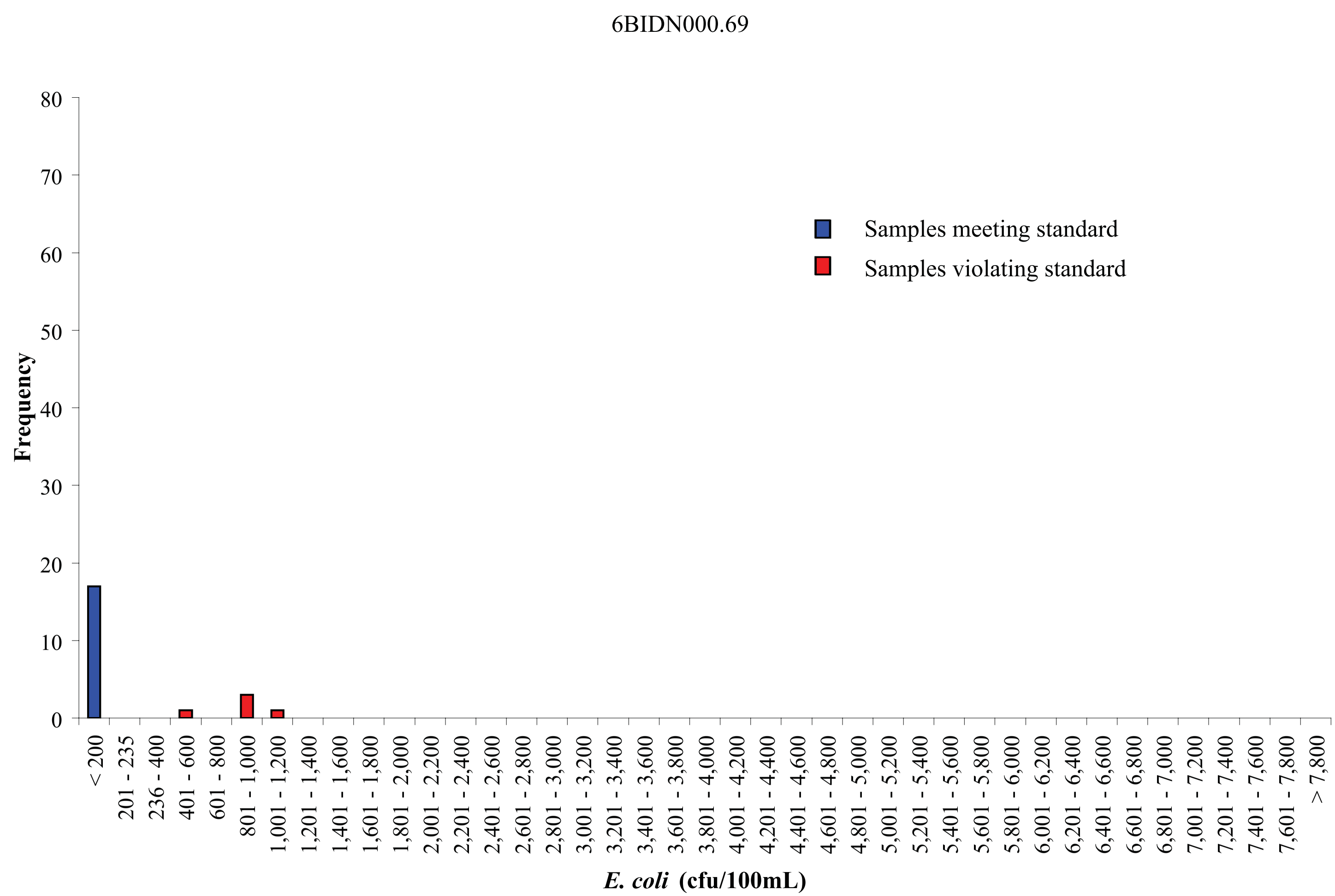

Figure A. 4 Frequency analysis of *E. coli* concentrations at station 6BIDN000.69 in the Indian Creek for the period from January 2007 to January 2011.

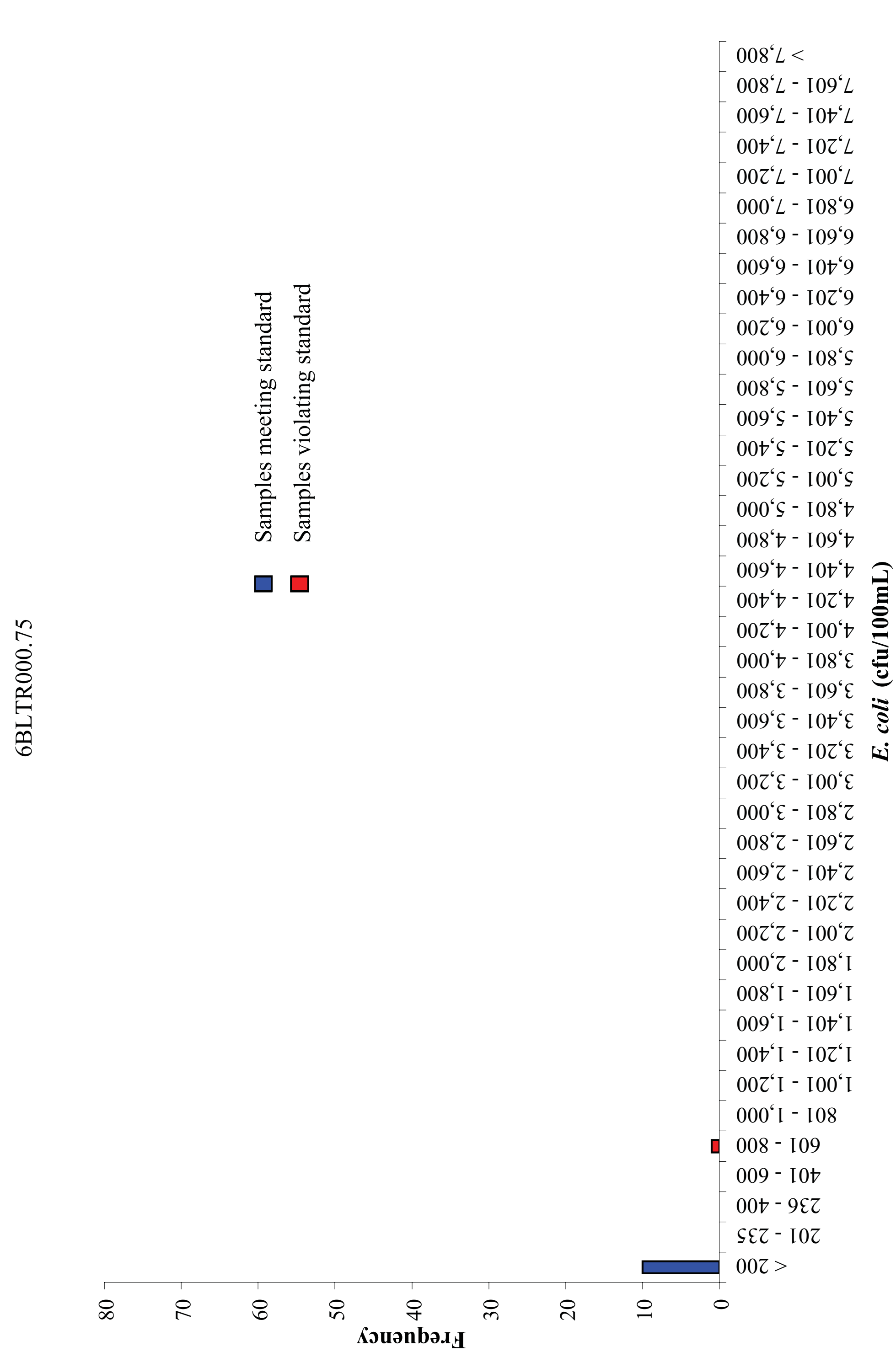

Figure A. 5 Frequency analysis of *E. coli* concentrations at station 6BLTR000.75 in the Little River for the period from January 2007 to November 2008.

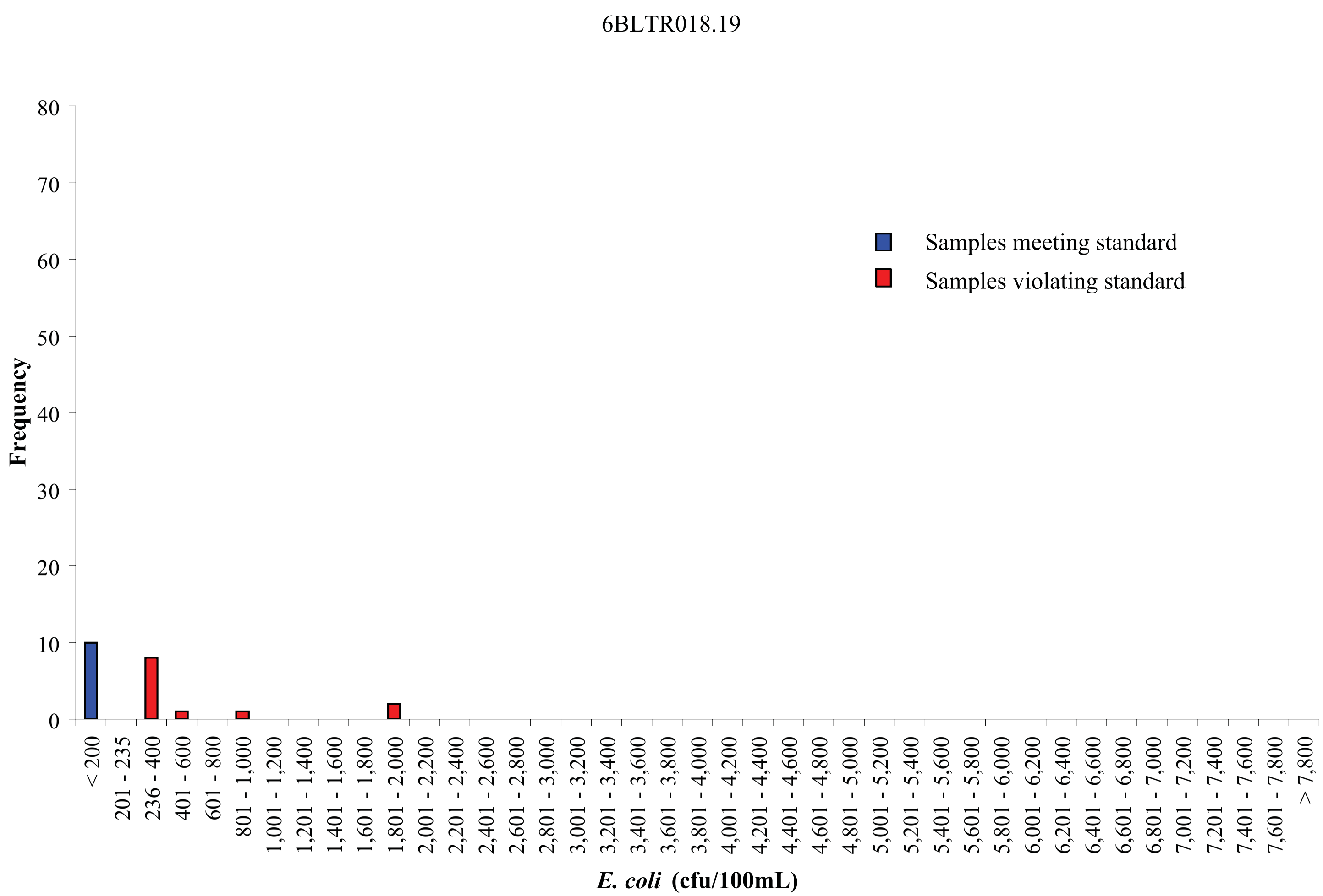

Figure A. 6 Frequency analysis of *E. coli* concentrations at station 6BLTR018.19 in the Little River for the period from January 2007 to January 2011.

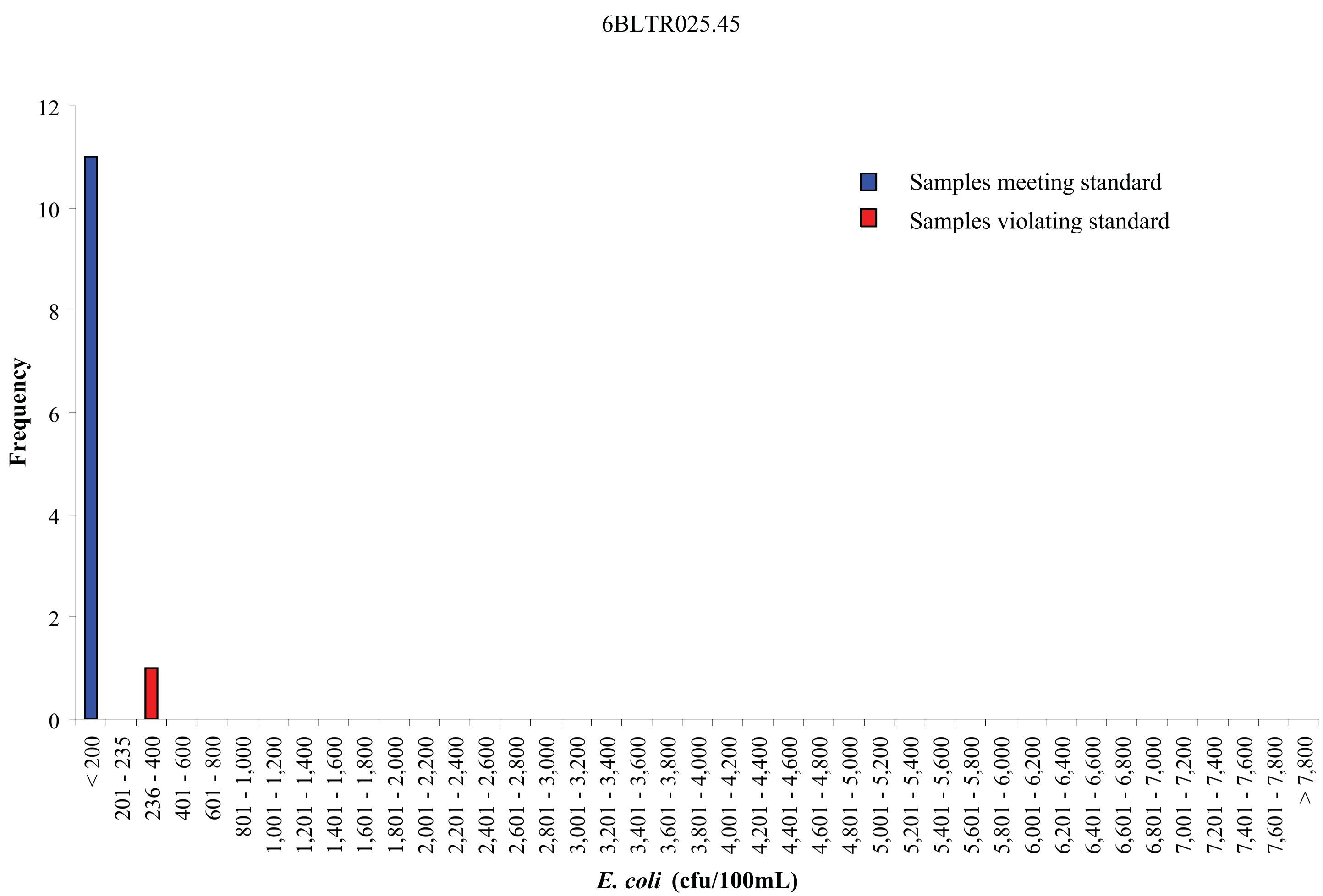

Figure A. 7 Frequency analysis of *E. coli* concentrations at station 6BLTR025.45 in the Little River for the period from January 2007 to November 2008.

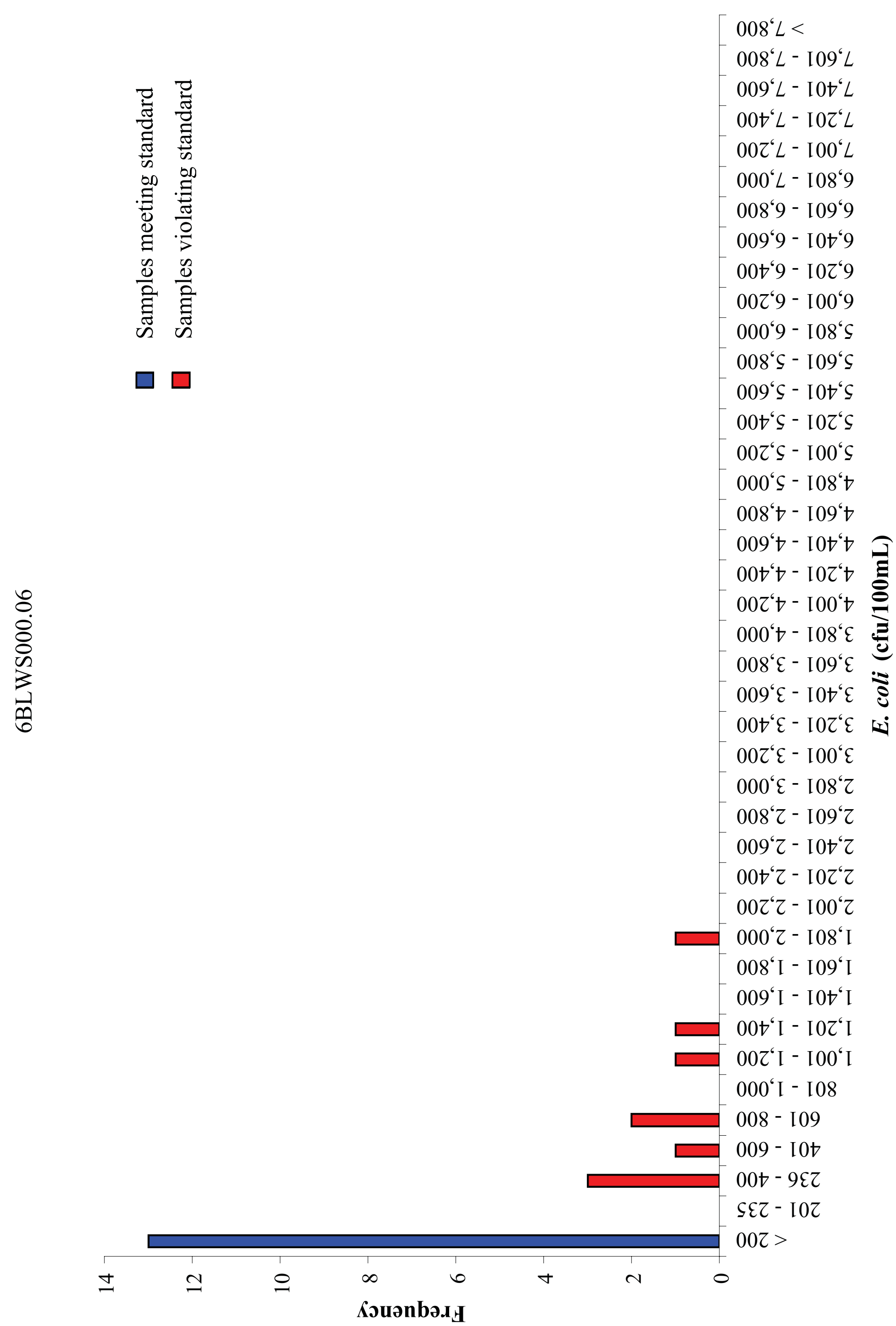

Figure A. 8 Frequency analysis of *E. coli* concentrations at station 6BLWS000.06 in the Lewis Creek for the period from February 2007 to January 2011.

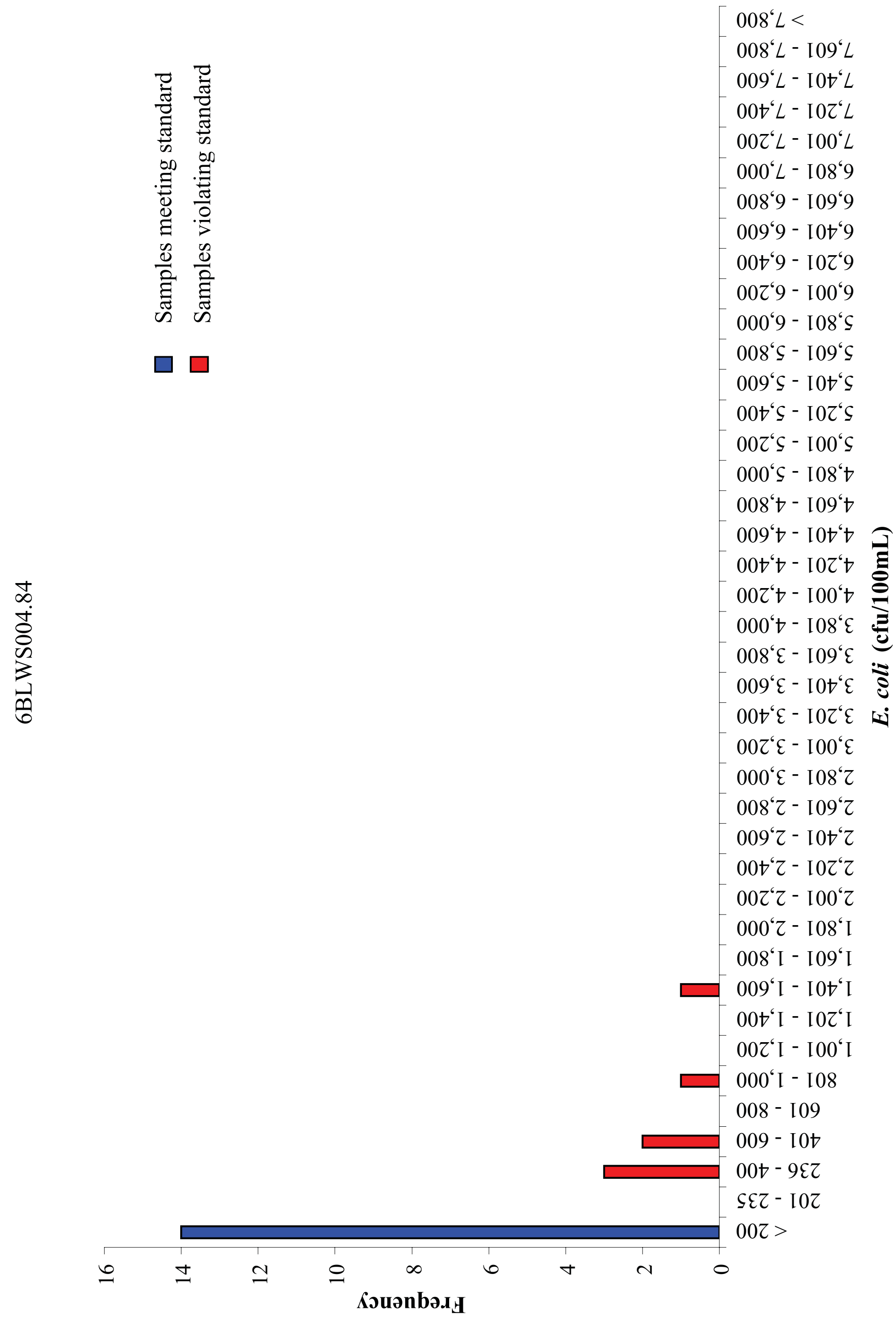

Figure A. 9 Frequency analysis of *E. coli* concentrations at station 6BLWS004.84 in the Lewis Creek for the period from February 2007 to January 2011.

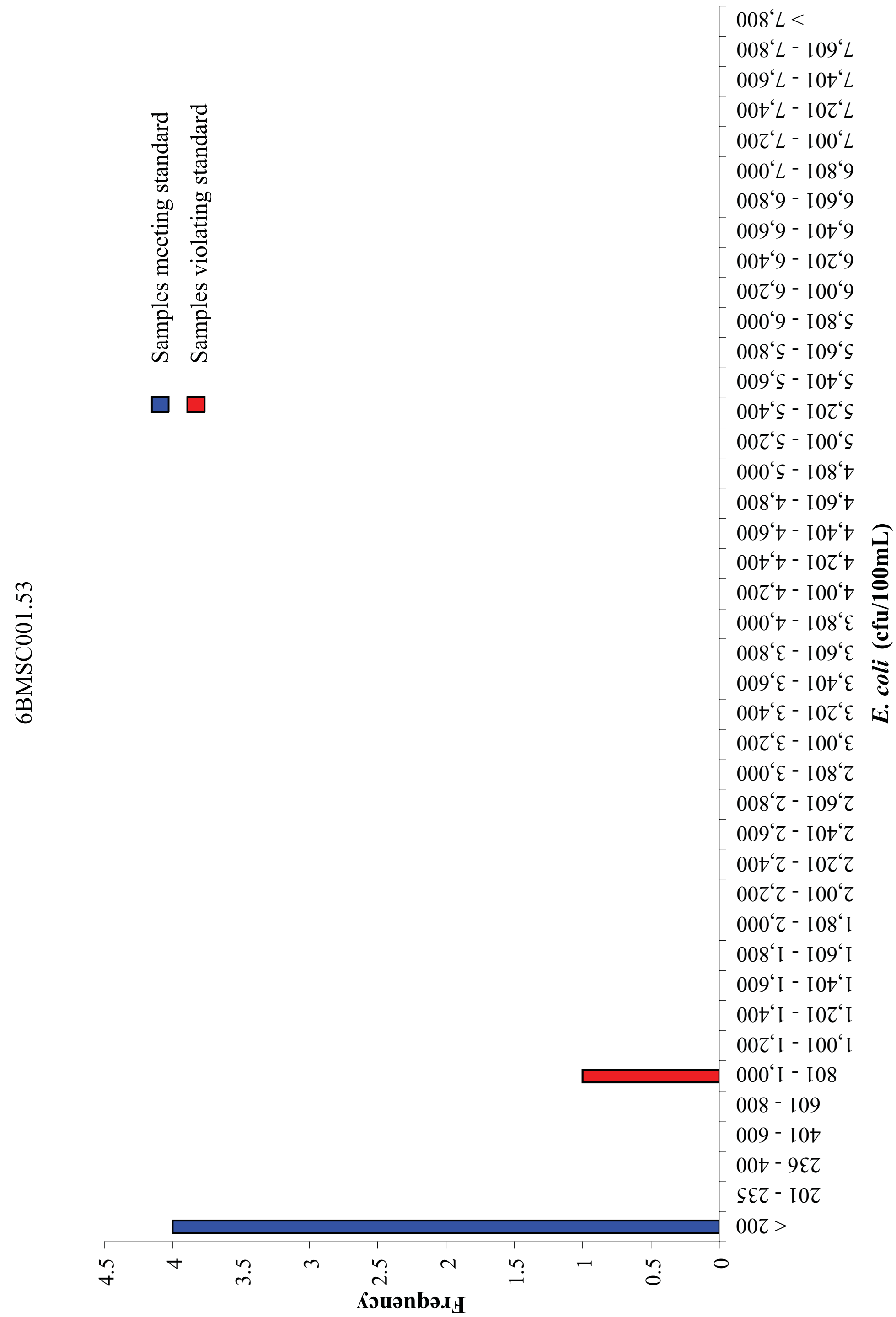

Figure A. 10 Frequency analysis of *E. coli* concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from January 2007 to April 2010.

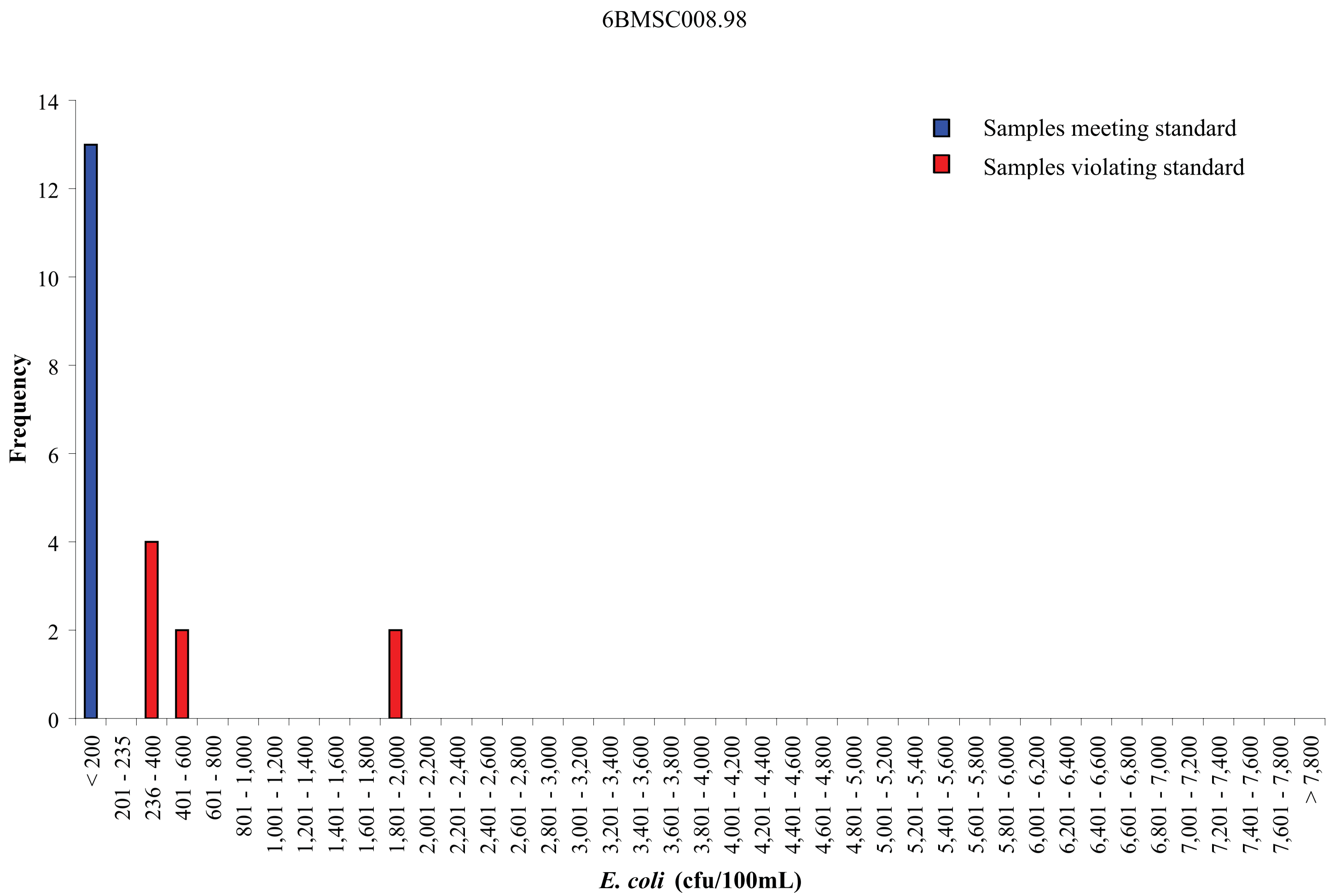

Figure A. 11 Frequency analysis of *E. coli* concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from January 2007 to January 2011.

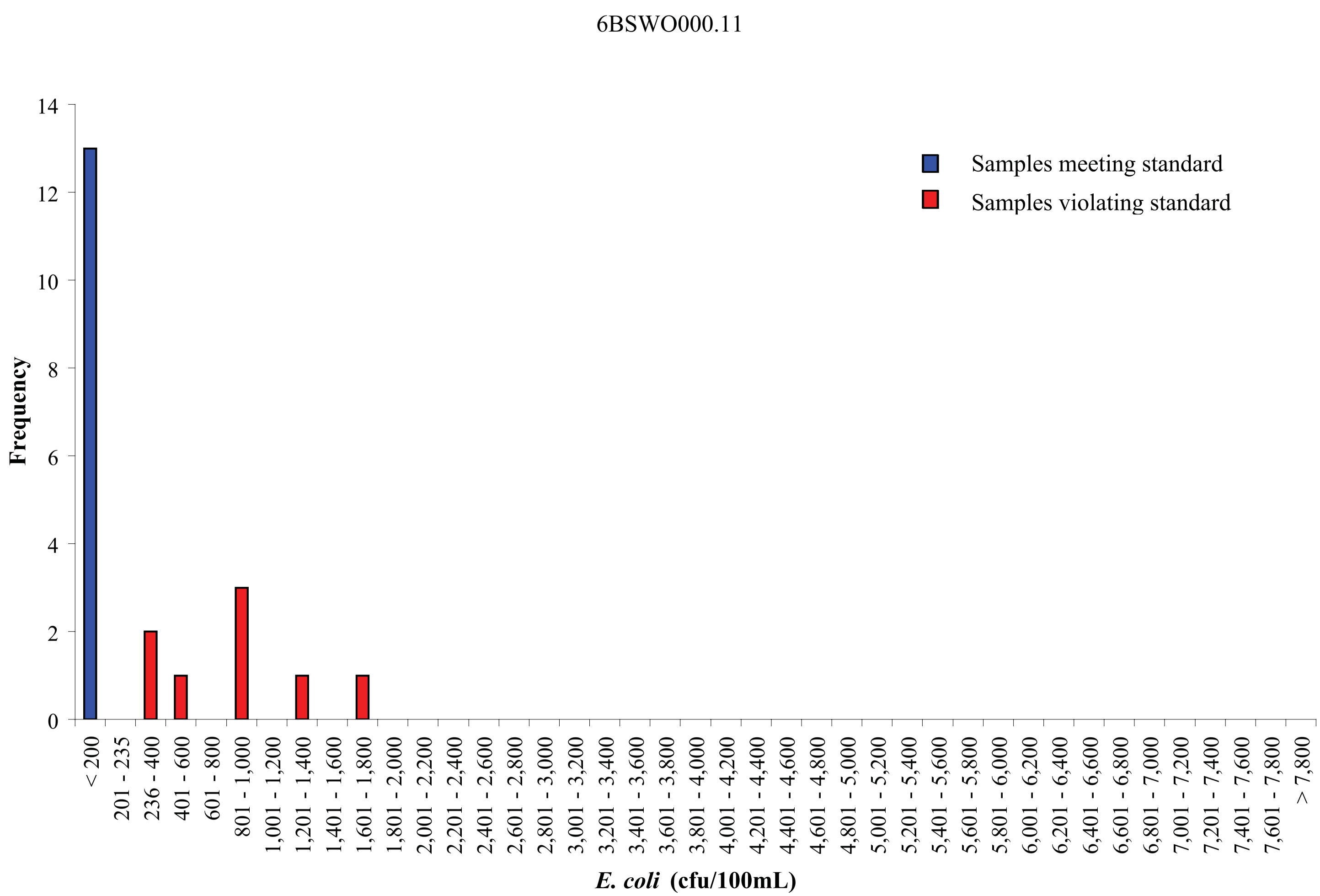

Figure A. 12 Frequency analysis of *E. coli* concentrations at station 6BSWO000.11 in the Swords Creek for the period from April 2009 to January 2011.

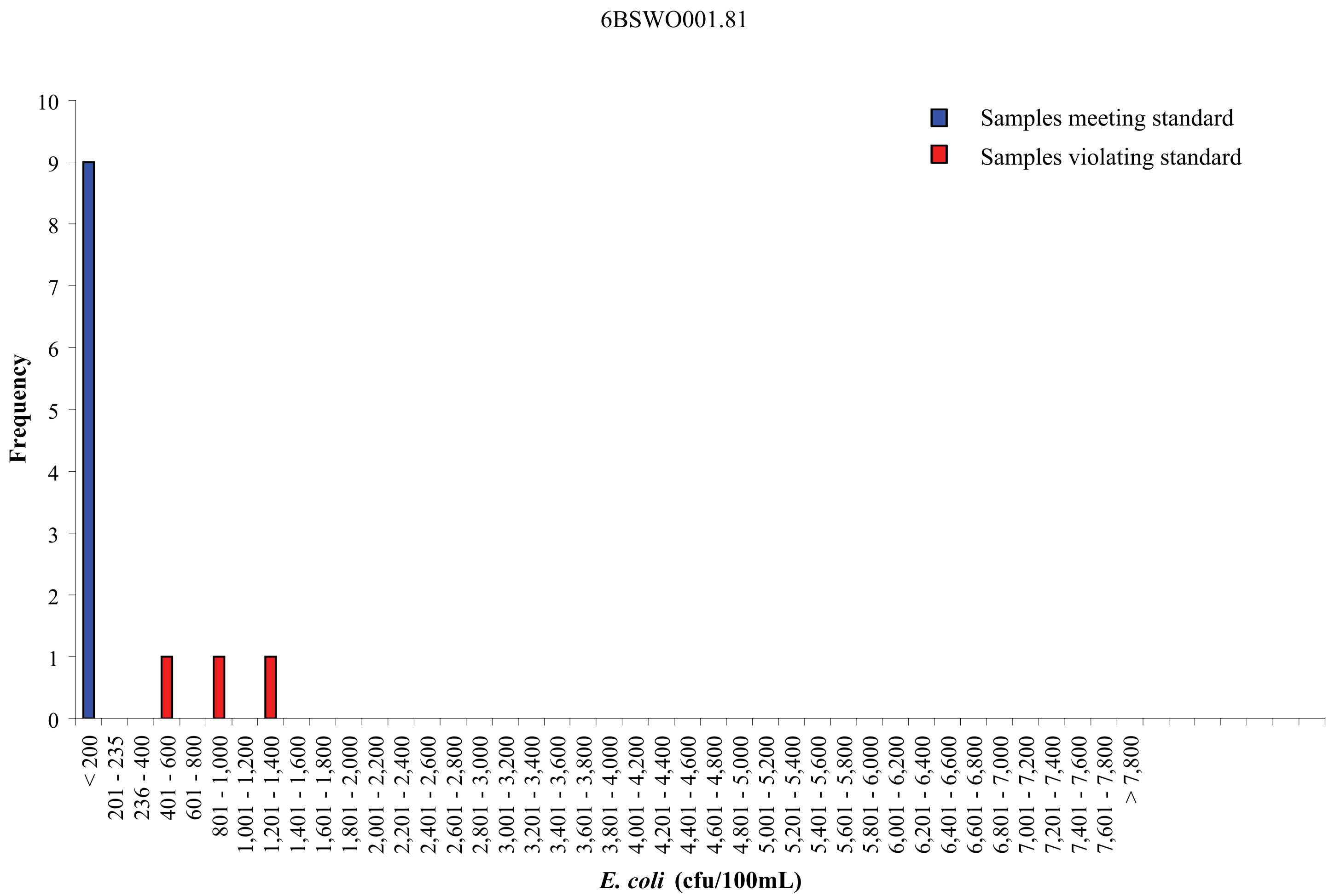

Figure A. 13 Frequency analysis of *E. coli* concentrations at station 6BSWO001.81 in the Swords Creek for the period from February 2007 to December 2008.

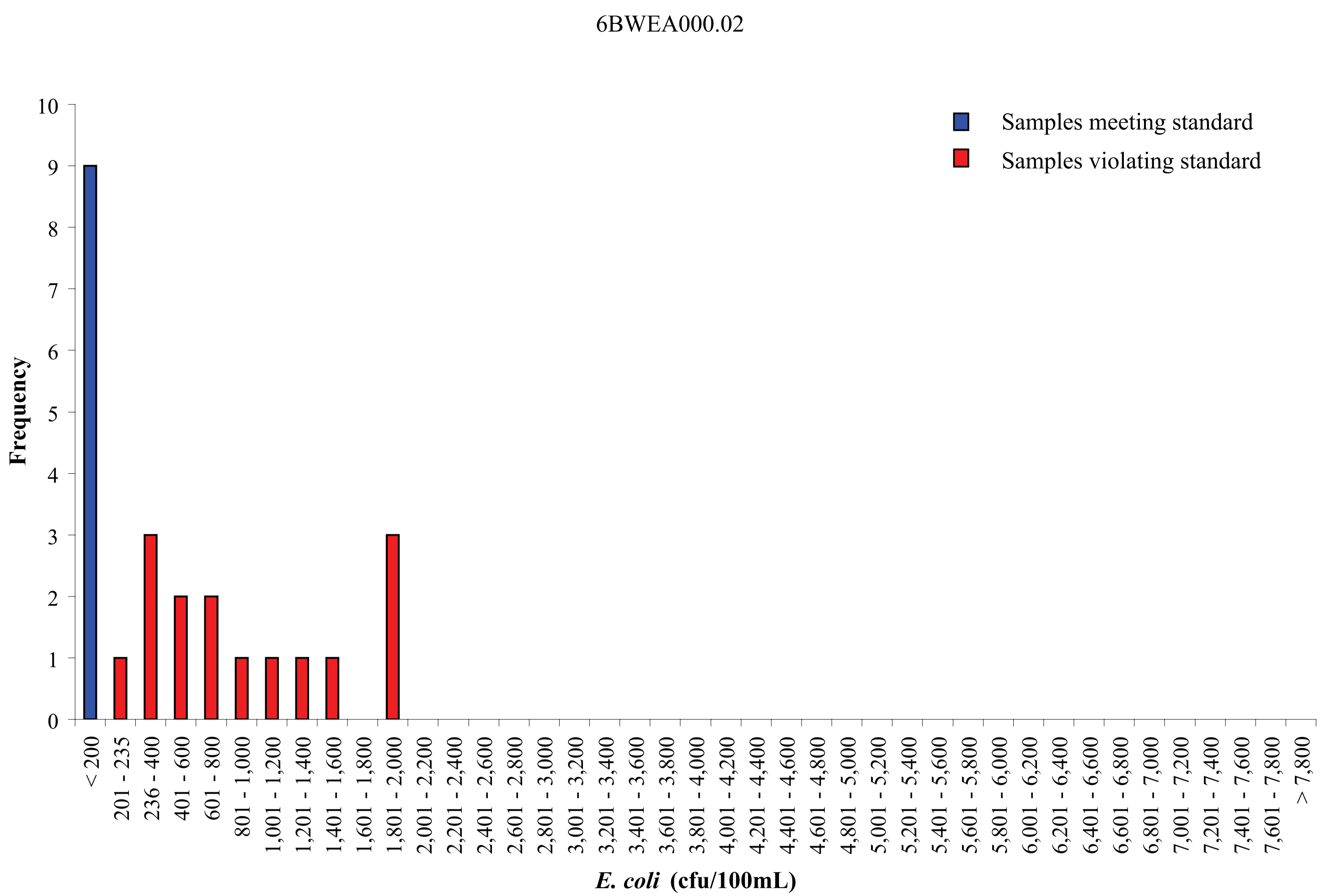

Figure A. 14 Frequency analysis of *E. coli* concentrations at station 6BWEA000.02 in the Weaver Creek for the period from August 2003 to December 2010.

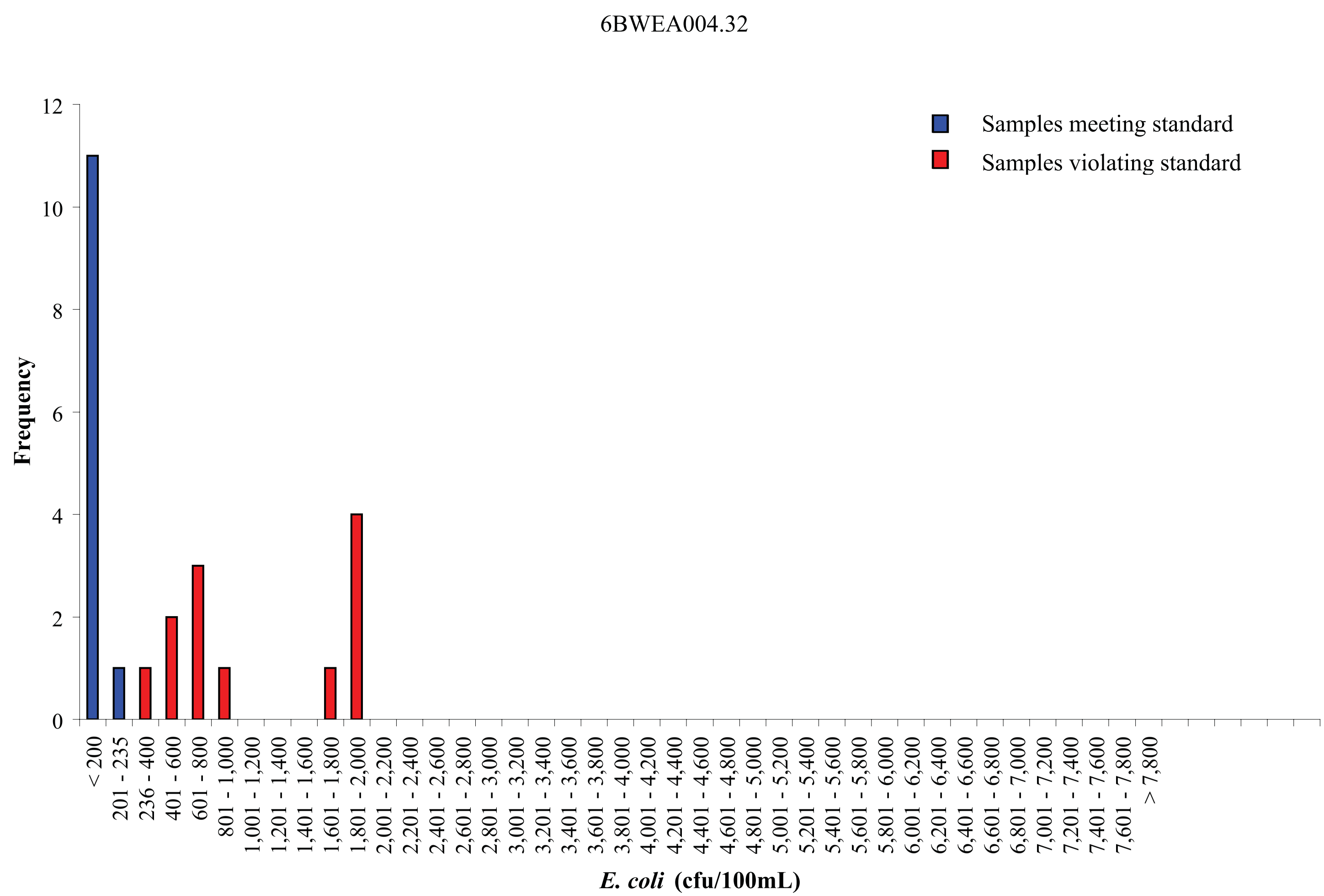

Figure A. 15 Frequency analysis of *E. coli* concentrations at station 6BWEA004.32 in the Weaver Creek for the period from August 2003 to December 2010.

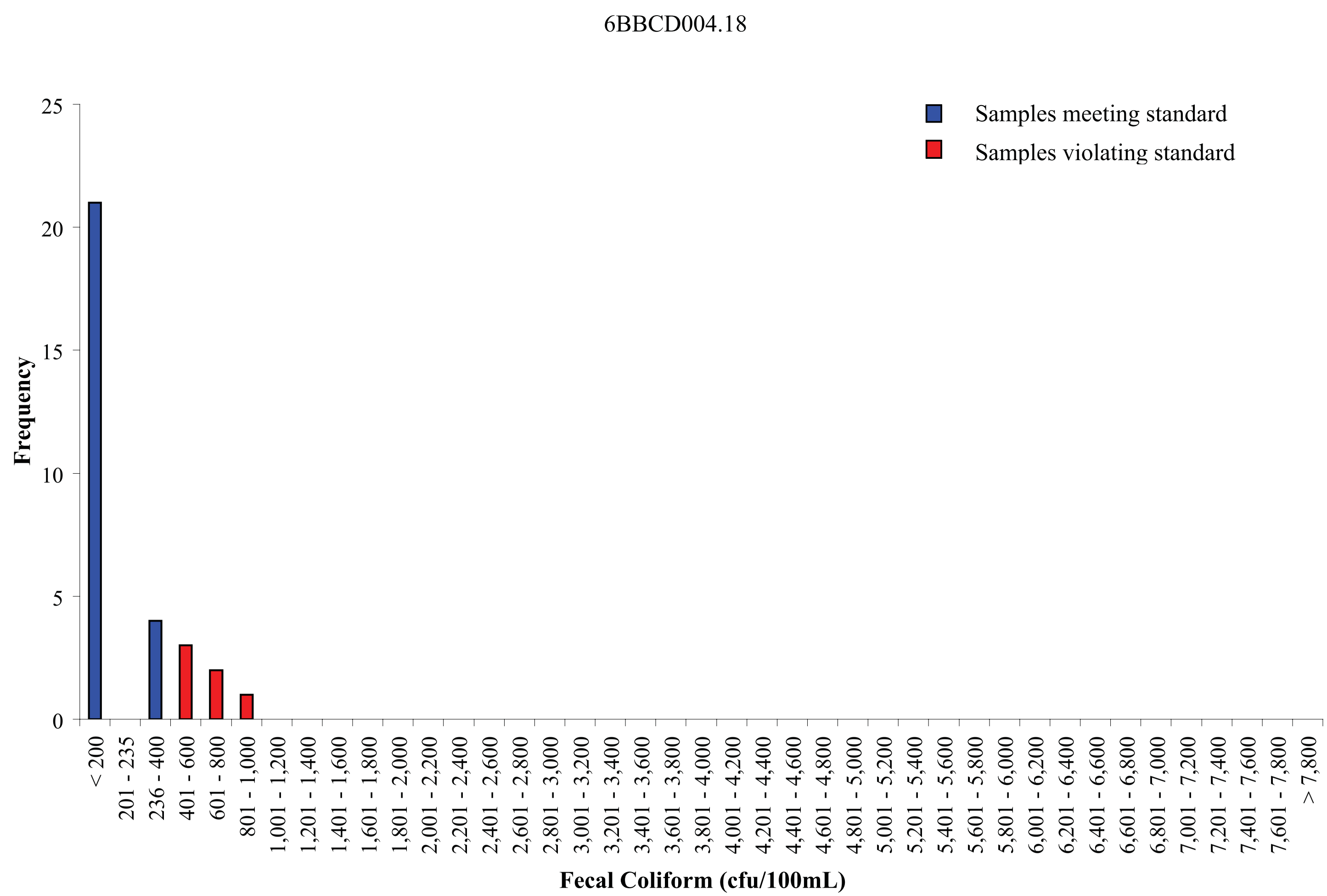

Figure A. 16 Frequency analysis of Fecal Coliform concentrations at station 6BBCD004.18 in Big Cedar Creek for the period from May 1994 to March 2001.

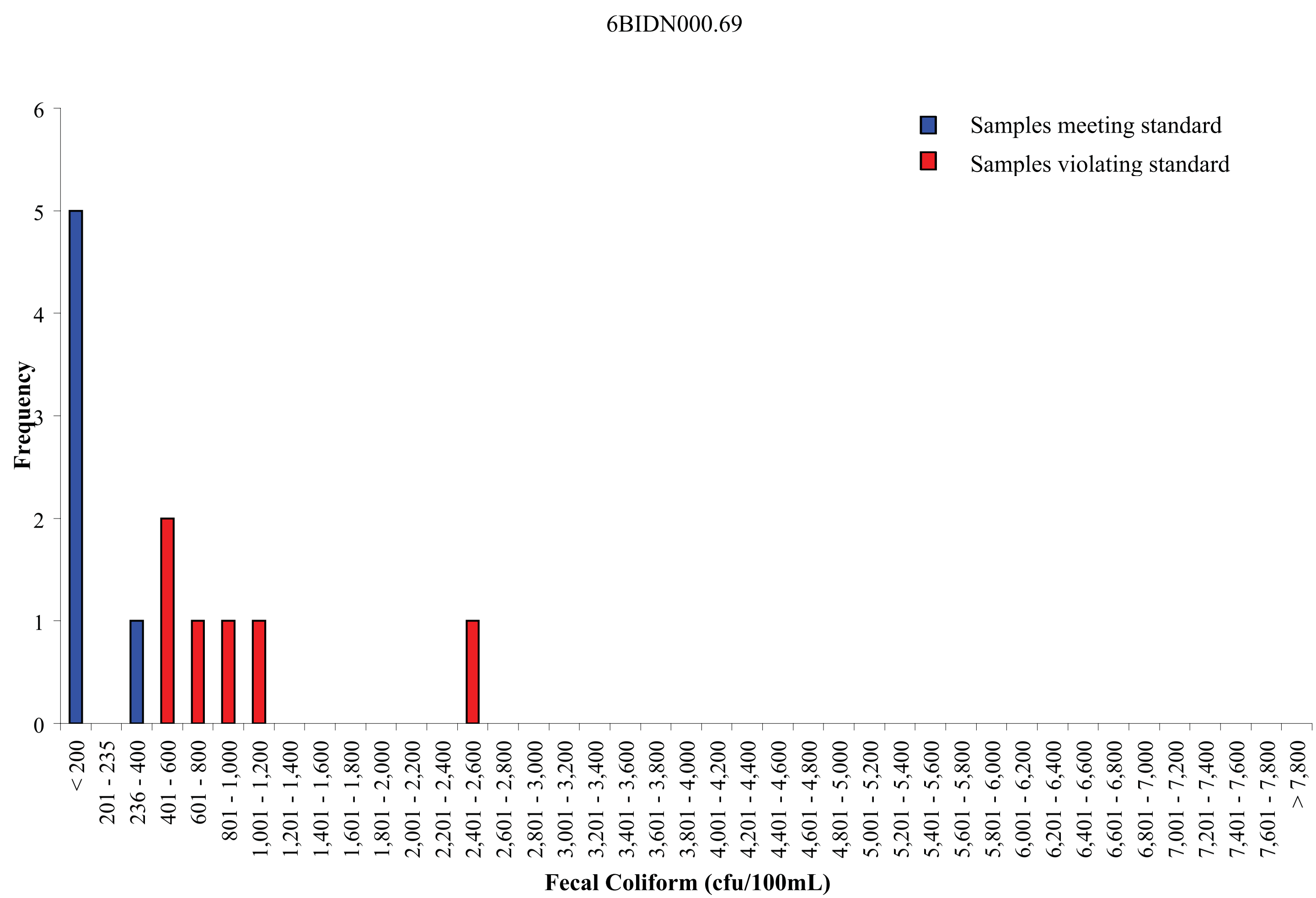

Figure A. 17 Frequency analysis of Fecal Coliform concentrations at station 6BIDN000.69 in Indian Creek for the period from August 2001 to June 2003.

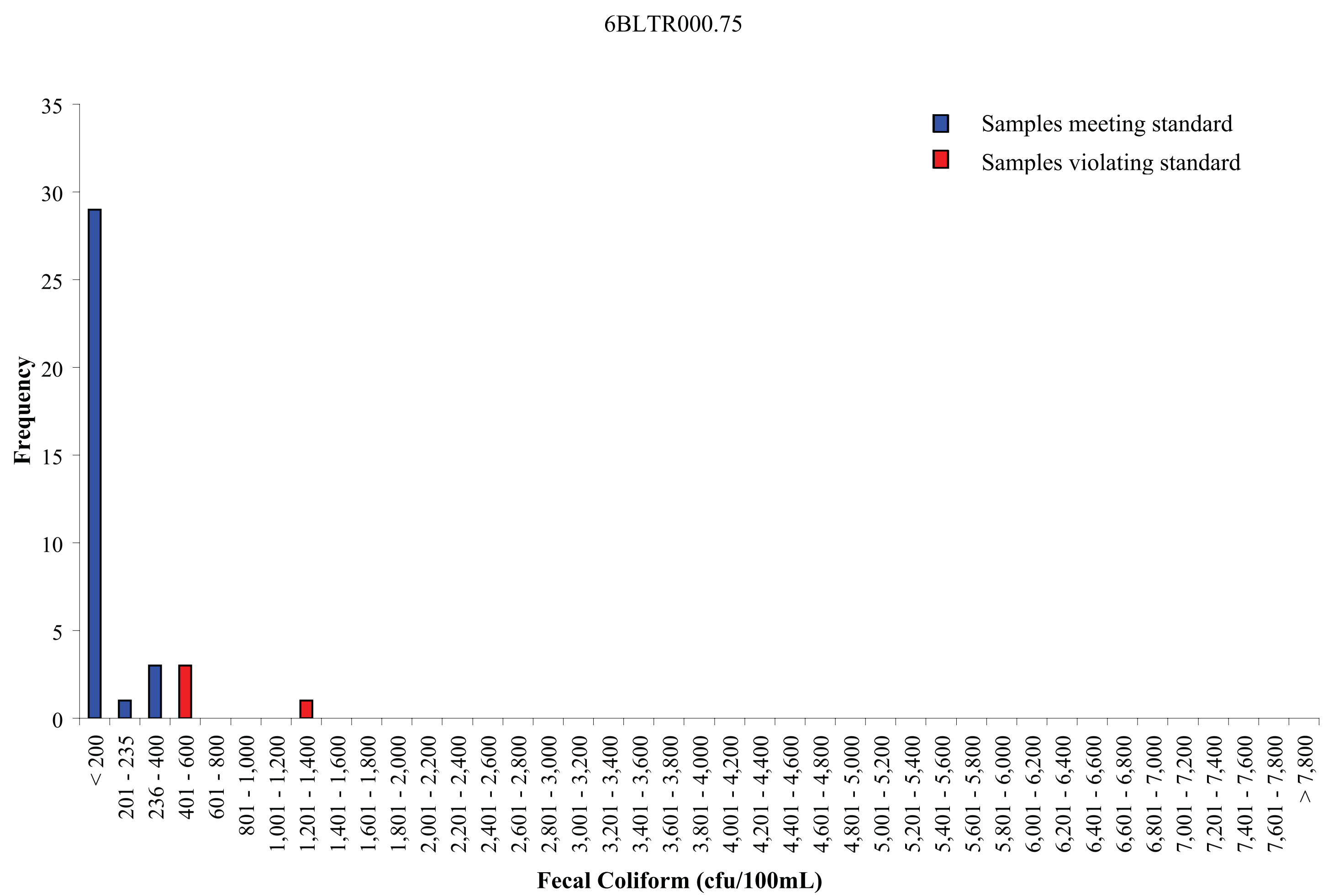

Figure A. 18 Frequency analysis of Fecal Coliform concentrations at station 6BLTR000.75 in the Little River for the period from September 1995 to June 2003.

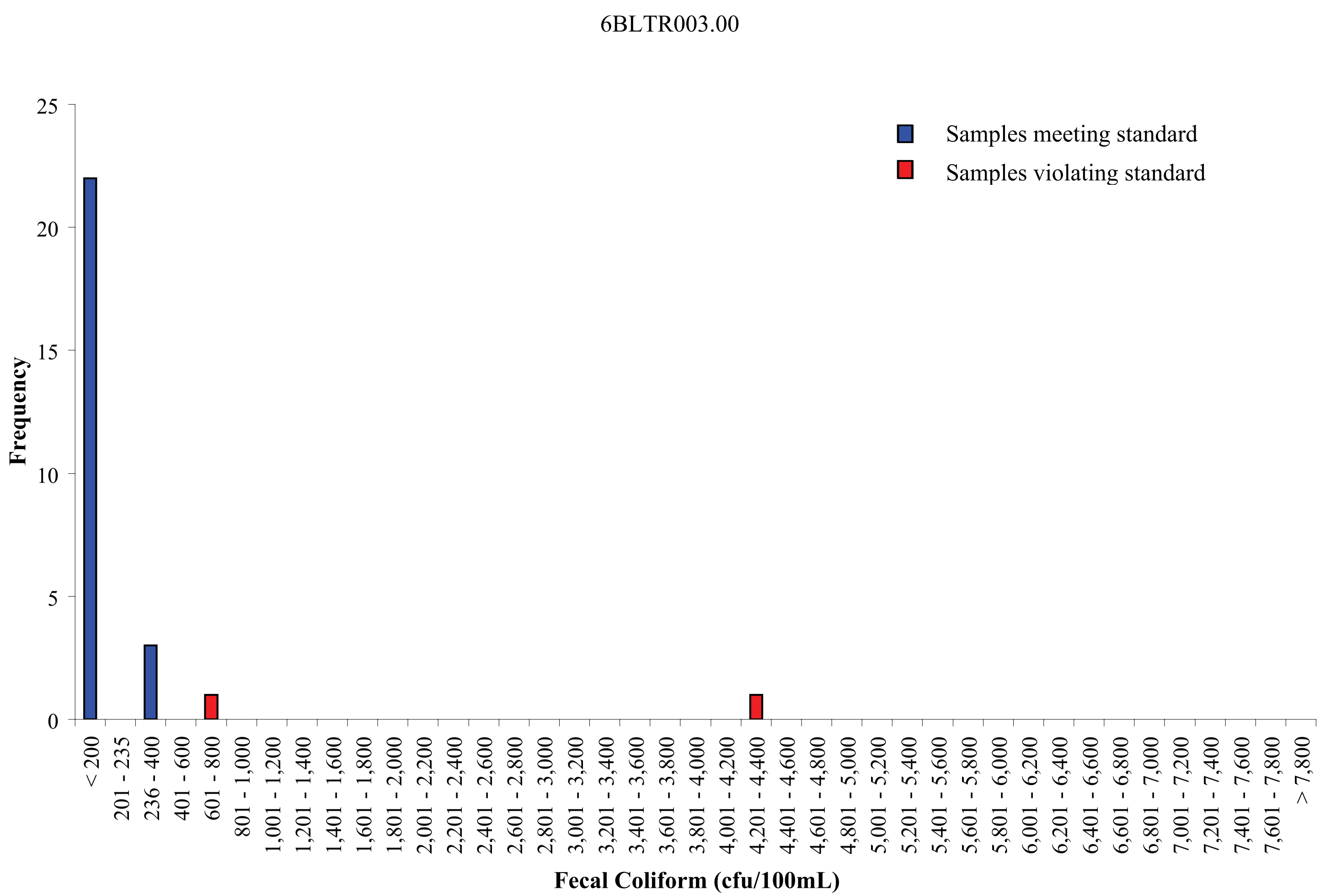

Figure A. 19 Frequency analysis of Fecal Coliform concentrations at station 6BLTR003.00 in the Little River for the period from January 1990 to March 1994.

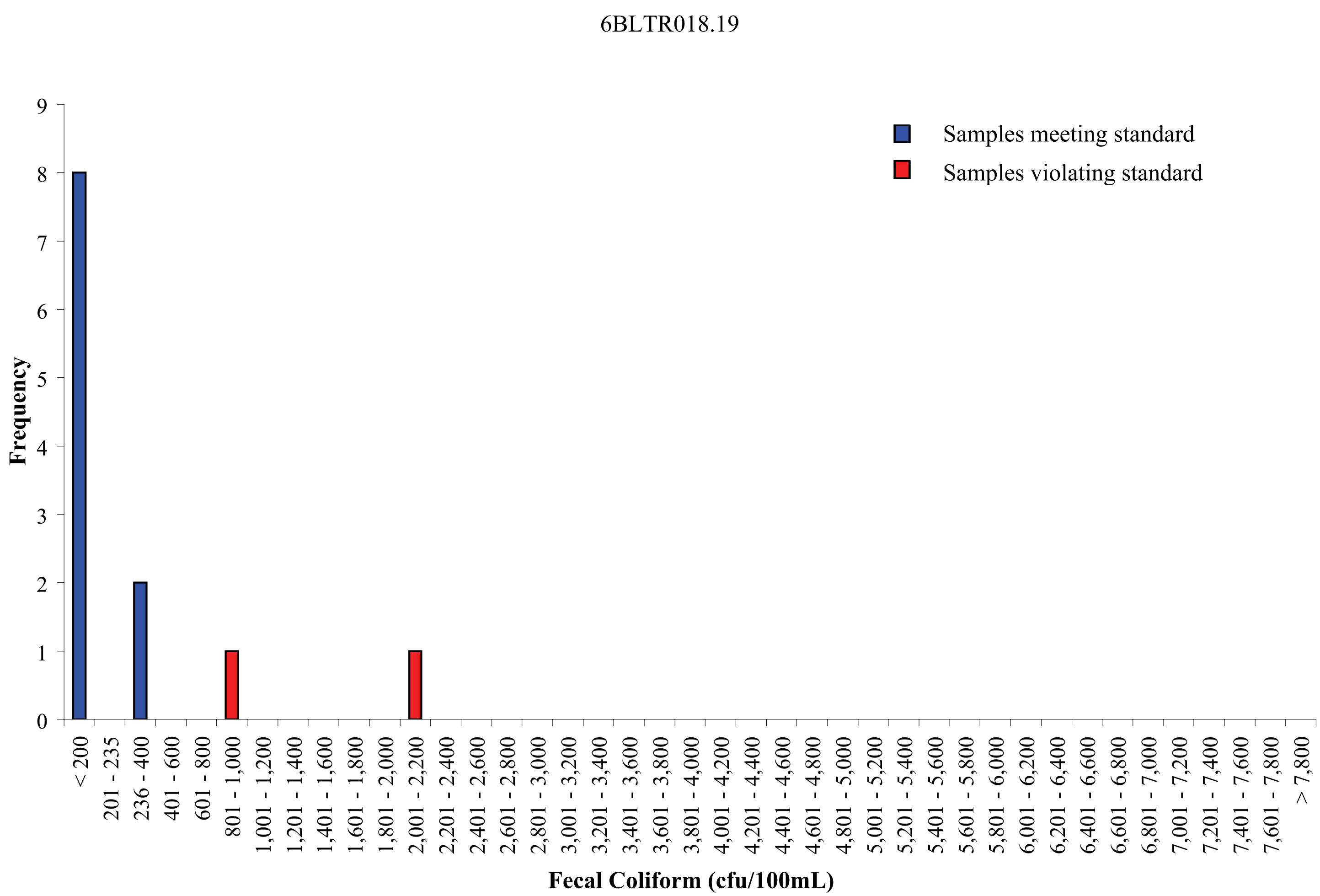

Figure A. 20 Frequency analysis of Fecal Coliform concentrations at station 6BLTR018.19 in the Little River for the period from August 2001 to June 2003.

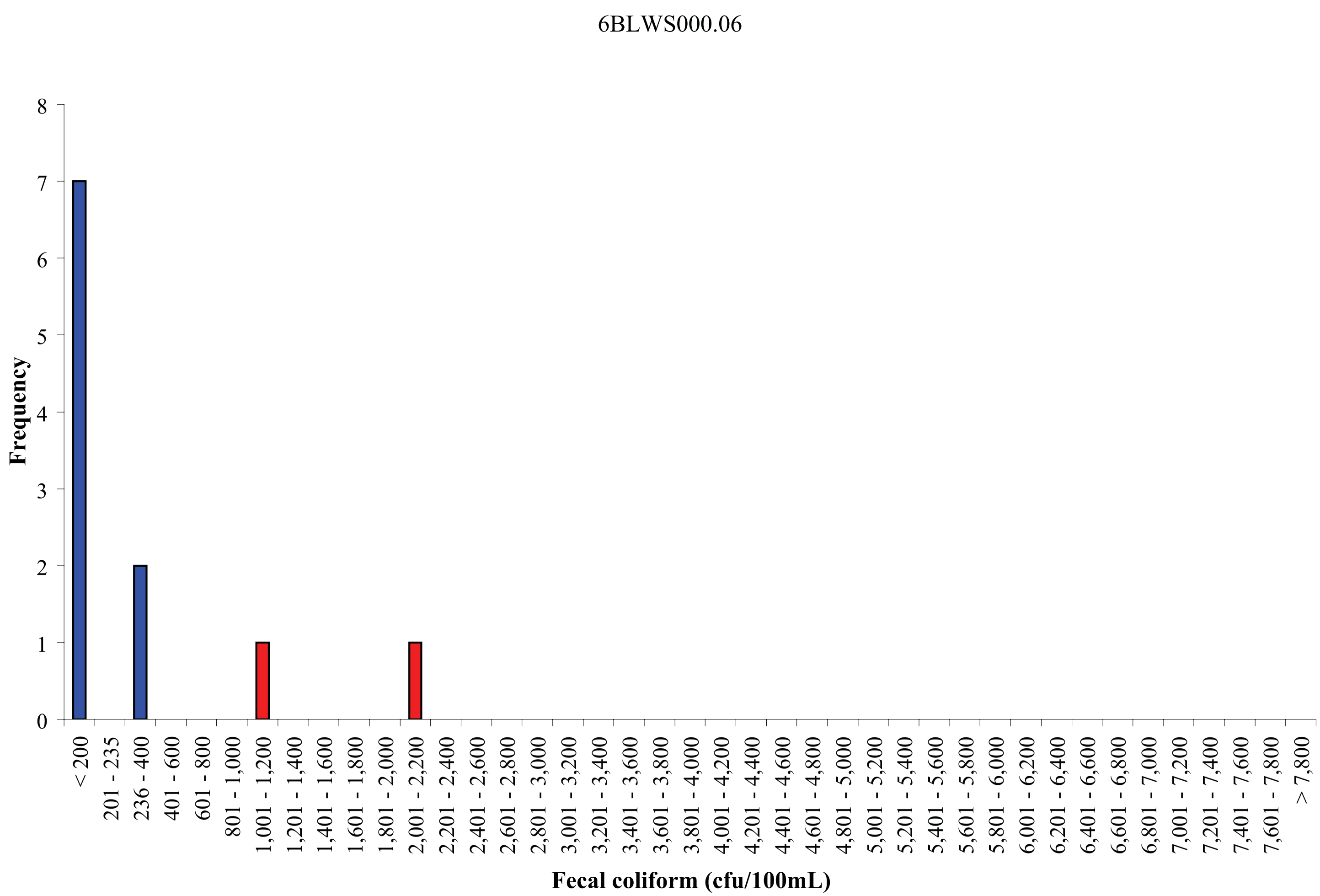

Figure A. 21 Frequency analysis of Fecal Coliform concentrations at station 6BWS000.06 in Lewis Creek for the period from August 2001 to June 2003.

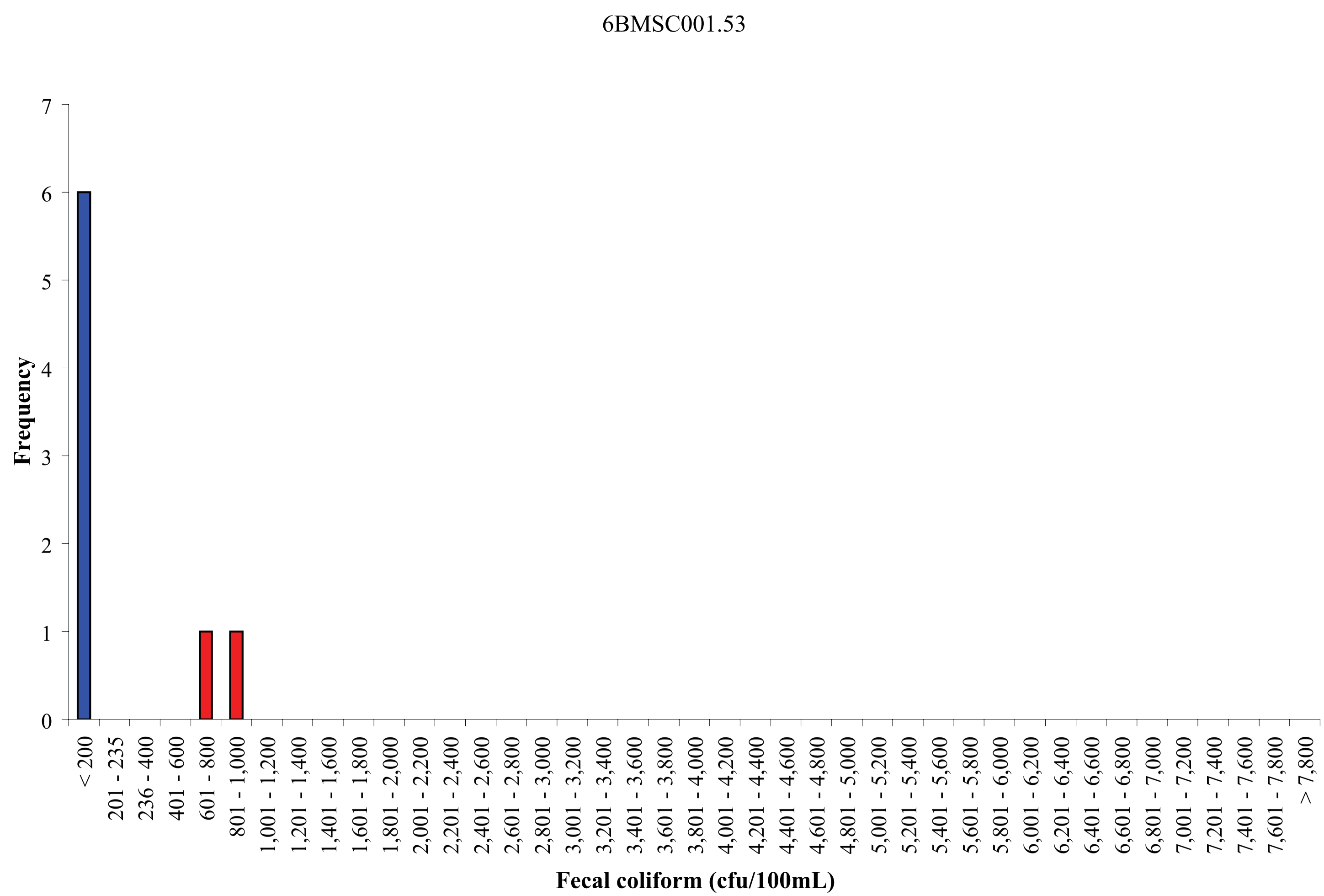

Figure A. 22 Frequency analysis of Fecal Coliform concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from August 2001 to June 2003.

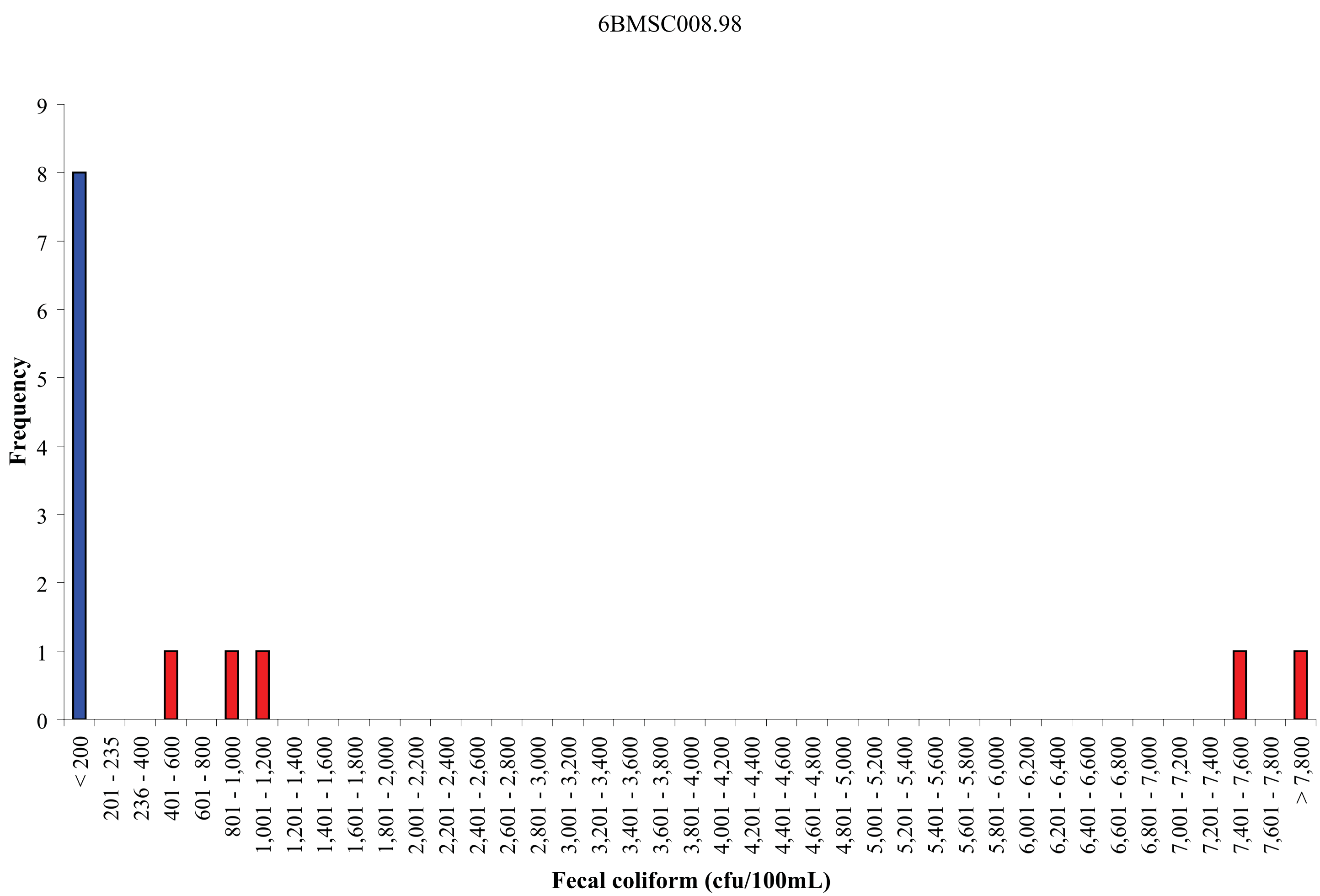

Figure A. 23 Frequency analysis of Fecal Coliform concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from August 2001 to March 2007.

APPENDIX C BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Modeling Procedure: Linking the Sources to the Endpoint

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of the TMDL for the Middle Clinch River watershed study area, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate streamflow, overland runoff and to perform TMDL allocations.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

Model Setup

Daily precipitation data was available within the watershed at the Richlands NCDC Coop station #447174. Missing values were filled using daily precipitation from the Lebanon NCDC Coop station #444777, and then from the Abingdon NCDC Coop station #440021 as needed . The final filled daily precipitation was disaggregated using the hourly station data from Bristol Tri City Airport NCDC Coop station #401094.

To adequately represent the spatial variation in the watershed, the Middle Clinch River watershed drainage area was divided into twenty-one (21) subwatersheds (Figure C.1). The rationale for choosing these subwatersheds was based on the availability of water quality data, the stream network configuration, and the limitations of the HSPF model. All of the subwatersheds upstream of subwatershed 2 were used in hydrologic calibration since they were upstream of the flow gage with observed data. The flow gage was the USGS Clinch River gage (#03524000) in Cleveland, VA (at the outlet of subwatershed 19). All subwatersheds were used in the bacteria calibration.

Figure C.1 shows all subwatersheds, which were used to achieve the unified model. Table C.1 notes the subwatersheds contained within each impairment, the impaired stream segments, and the outlet subwatershed for each impairment.

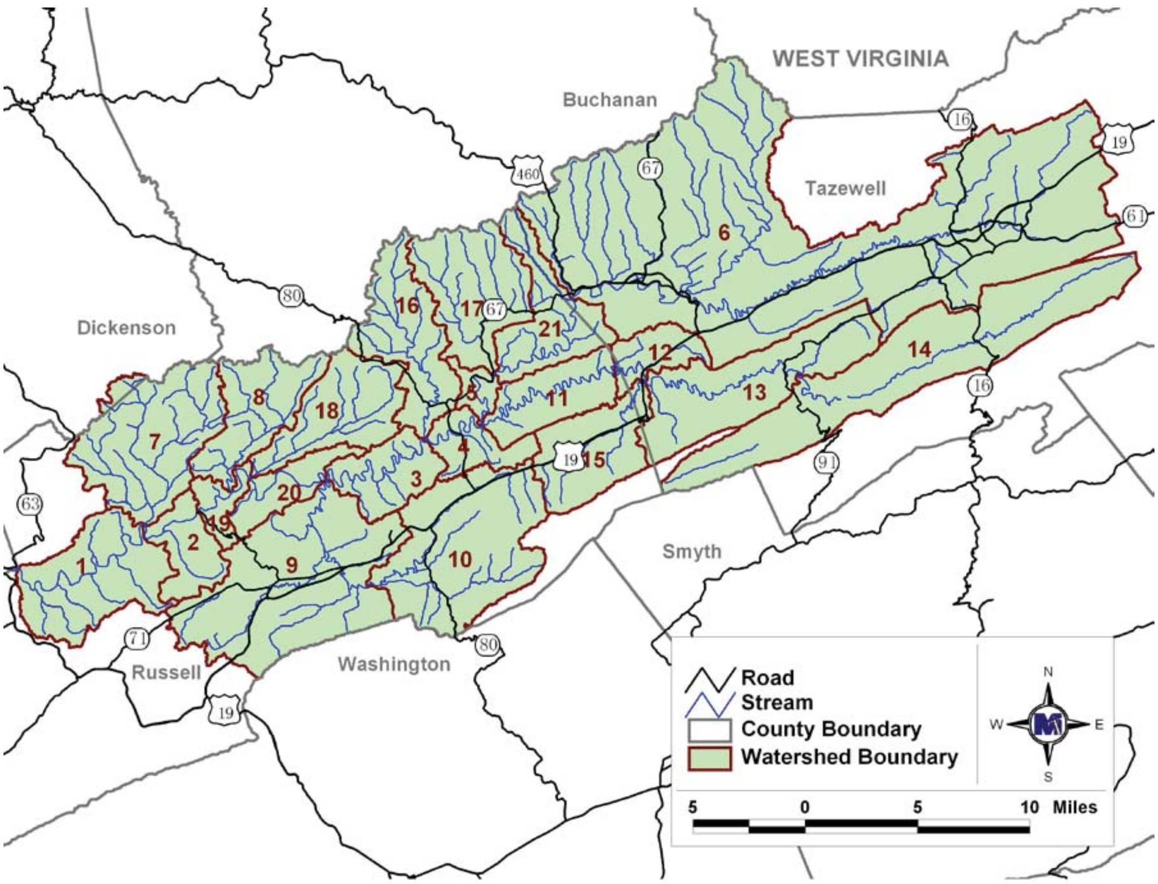

Figure C.1 All subwatersheds delineated for modeling in the Middle Clinch River watershed study area.

Table C.1 Impairments and subwatersheds within the Middle Clinch River watershed study area.

Impairment	Impaired Subwatershed (s)	Outlet	Contributing Subwatersheds
Indian Creek VAS-P05R_IDN01A04	15	15	15
Clinch River VAS-P07R_CLN01A00	2, 19, 20	2	All (except 1 and 7)
Big Cedar Creek VAS-P06R_BCD01A98	9	9	9, 10
Big Cedar Creek VAS-P06R_BCD02A02	9	Big Cedar Creek Segment BCD01A98	9, 10
Big Cedar Creek VAS-P06R_BCD02A00	9	Big Cedar Creek Segment BCD02A02	9, 10
Big Cedar Creek VAS-P06R_BCD03A00	9	Big Cedar Creek Segment BCD02A00	9, 10
Loop Creek VAS-P06R_LOO01A06	10	10	10
Burgess Creek VAS-P06R_BUG01A06	9	Big Cedar Creek Segment BCD03A00	9
Elk Garden Creek VAS-P06R_EKG01A06	10	10	10
Weaver Creek VAS-P07R_WEA01A06	8	8	8
Thompson Creek VAS-P07R_TMP01A06	18	18	18
Lewis Creek VAS-P04R_LWS01A98	16	16	16
Lewis Creek VAS-P04R_LWS01A10	16	16	16
Hess Creek VAS-P04R_HES01A10	17	Swords Creek	17
Swords Creek VAS-P04R_HES01A10	17	17	17
Little River VAS-P05R_LTR02A00	13	13	13, 14
Little River VAS-P05R_LTR02A02	12	12	12, 13, 14, 15
Dumps Creek VAS-P08R_DUM01A94	7	7	7
Maiden Spring Creek VAS-P05R_MSC01A02	14	14	14
Maiden Spring Creek VAS-P05R_MSC01C04	14	Maiden Spring Creek segment MSC01A02	14

In an effort to standardize modeling procedures across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

Ten (10) land uses were identified in the watershed. These land uses were obtained by merging different sources including the MRLC land use grid, active mining layers provided by the Virginia Department of Mines, Minerals, and Energy (DMME), topographic maps (for delineating abandoned mine lands), and aerial photography of the region. The 10 land use types are given in Table C.2. Within each subwatershed, up to the ten land use types were represented. Each land use in each subwatershed has hydrologic parameters (e.g., average slope length) and pollutant behavior parameters (e.g., E. coli accumulation rate) associated with it. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in four IMPLND types, while there are ten PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (e.g., slope length) vary with the particular subwatershed in which they are located. Others vary with the season (e.g., upper zone storage) to account for plant growth, die-off, and removal.

Figure C.2 shows the land uses used in modeling the Middle Clinch River Watershed study area. Table C.3 shows the breakdown of land uses within the drainage area of each impairment. These acreages represent only what is within the boundaries of the Middle Clinch River Watershed study area.

Table C.2 Consolidated land use categories for the Middle Clinch River watershed drainage area used in HSPF modeling.

TMDL Land use Categories	Pervious / Impervious (%)
Barren	Pervious (94%) Impervious (6%)
Cropland	Pervious (100%)
Commercial	Pervious (40%) Impervious (60%)
Forest	Pervious (100%)
Gas Wells	Pervious (94%) Impervious (6%)
Livestock Access	Pervious (100%)
Pasture	Pervious (100%)
Residential	Pervious (90%) Impervious (10%)
Reclaimed Mine Land	Pervious (100%)
Water	Pervious (100%)

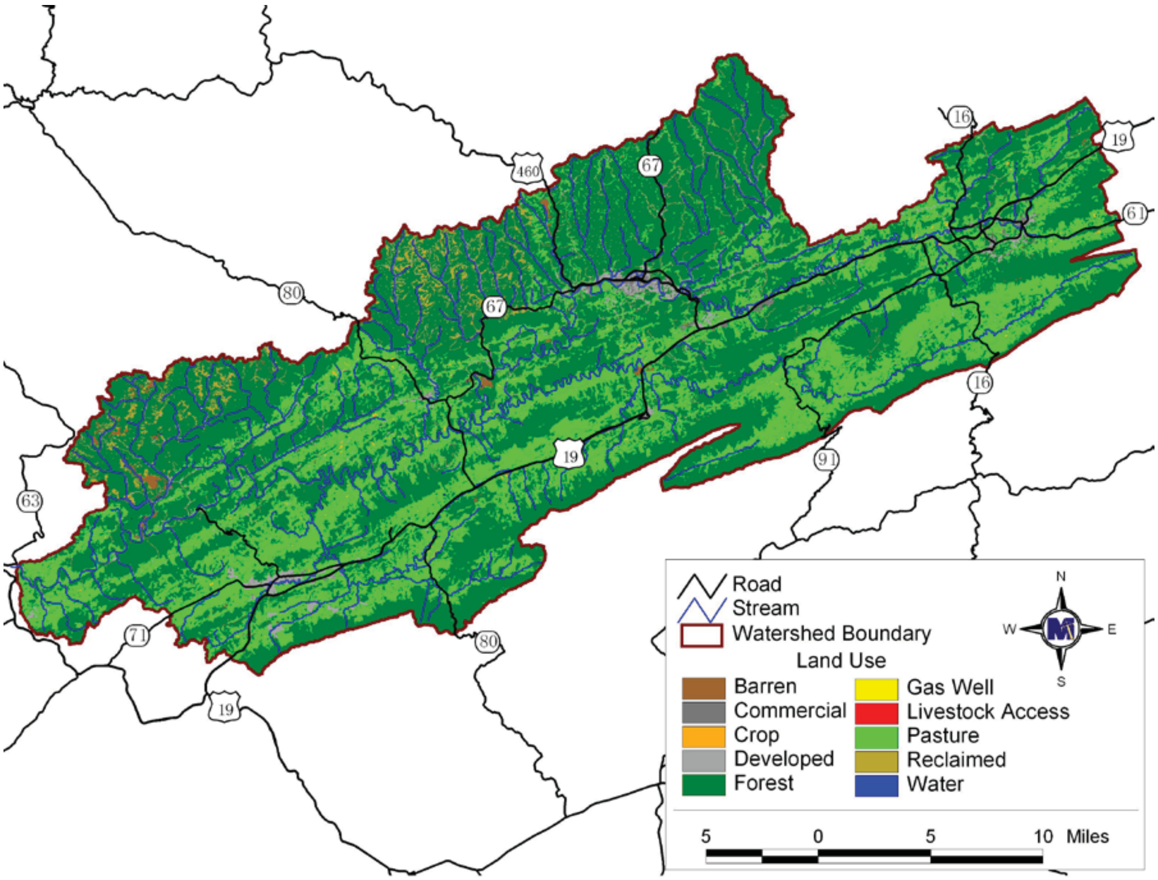

Figure C.2 Land uses in the Middle Clinch River watershed study area.

Table C.3 Spatial distribution of land use types in acres in the Middle Clinch River watershed study area.

Sub-Water-shed	Barren	Commercial	Crop	Forest	Gas Wells	LAX*	Pasture	Re-claimed Mine	Developed	Water	Total
1	71	59	49	8,902	0	74	6,026	0	891	306	**16,378**
2	13	21	23	3,906	0	10	2,148	0	344	79	**6,544**
3	1	13	59	4,686	0	26	2,512	0	487	246	**8,029**
4	14	17	13	2,530	0	27	2,403	0	376	118	**5,498**
5	152	34	13	1,404	0	2	434	0	201	53	**2,293**
6	294	3,062	243	79,143	193	317	21,834	45	8,783	635	**114,549**
7	669	247	3	15,915	43	1	196	2,012	937	284	**20,309**
8	17	63	10	8,636	20	37	1,707	313	569	63	**11,434**
9	74	306	152	13,173	0	108	15,465	0	3,086	160	**32,524**
10	38	13	167	14,061	0	129	9,736	0	943	103	**25,190**
11	1	3	45	5,576	0	31	3,148	0	257	149	**9,211**
12	94	115	53	2,321	0	16	1,882	0	482	54	**5,017**
13	39	3	41	11,776	0	55	6,956	0	663	164	**19,697**
14	50	0	72	17,189	0	95	15,329	0	871	69	**33,675**
15	11	69	28	5,608	0	50	5,394	0	739	42	**11,942**
16	10	184	33	9,426	61	26	2,209	757	1,217	70	**13,994**
17	40	143	10	11,336	81	3	322	1,651	1,391	82	**15,059**
18	3	31	155	6,648	0	47	4,603	18	943	64	**12,511**
19	3	11	11	2,142	0	9	769	0	224	97	**3,266**
20	12	15	47	2,919	0	11	2,157	0	376	151	**5,689**
21	42	81	27	7,455	12	46	2,492	148	924	135	**11,362**
Total	**1,648**	**4,491**	**1,257**	**234,752**	**410**	**1,119**	**107,721**	**4,944**	**24,704**	**3,126**	**384,172**

*LAX is livestock access to a stream.

Die-off of fecal bacteria can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal bacteria entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). These data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2008), Digital Elevation Models (DEM), nautical charts, and bathymetry data was used. The NRCS has developed empirical formulas for estimating stream top width, cross-sectional area, average depth, and flow rate, at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the Middle Clinch River watershed. Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with distance for each subwatershed outlet (Figure C.3). Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile.

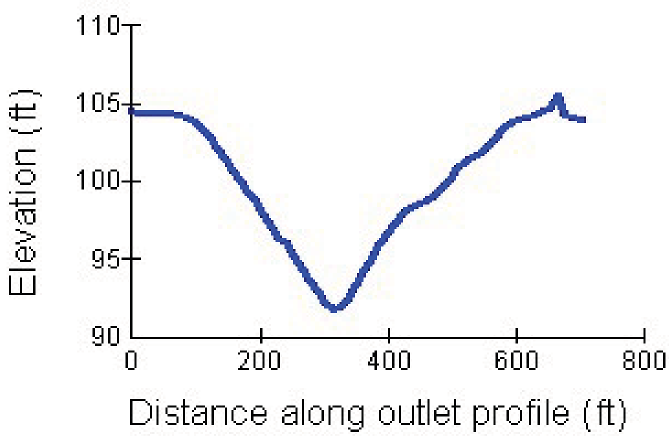

Figure C.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with values for resistance to flow (Manning's *n*) assigned based on recommendations by Brater and King (1976) and shown in Table C.4. The conveyance was calculated for each of the two floodplains and the main channel; these figures were then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from DEMs and a stream-flow network based on National Hydrography Dataset (NHD) data. The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth. An example of an F-table used in HSPF is shown in Table C.5.

Table C.4 Summary of Manning's roughness coefficients for channel cells*.

Section	Upstream Area (ha)	Manning's *n*
Intermittent stream	18 - 360	0.06
Perennial stream	360 and greater	0.05

*Brater and King (1976)

Table C.5 Example of an F-table calculated for an HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0	0	0	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Middle Clinch River watershed study area is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the Middle Clinch River watershed study area are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include non-point sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A description of the data used in these analyses is shown in Table 2.1 in Chapter 2. Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at four (4) VADEQ monitoring stations in the Middle Clinch River watershed study area (Figures C.4 - Figure C.25). This demonstrates that this stream should have all flow regimes represented in the allocation modeling time period.

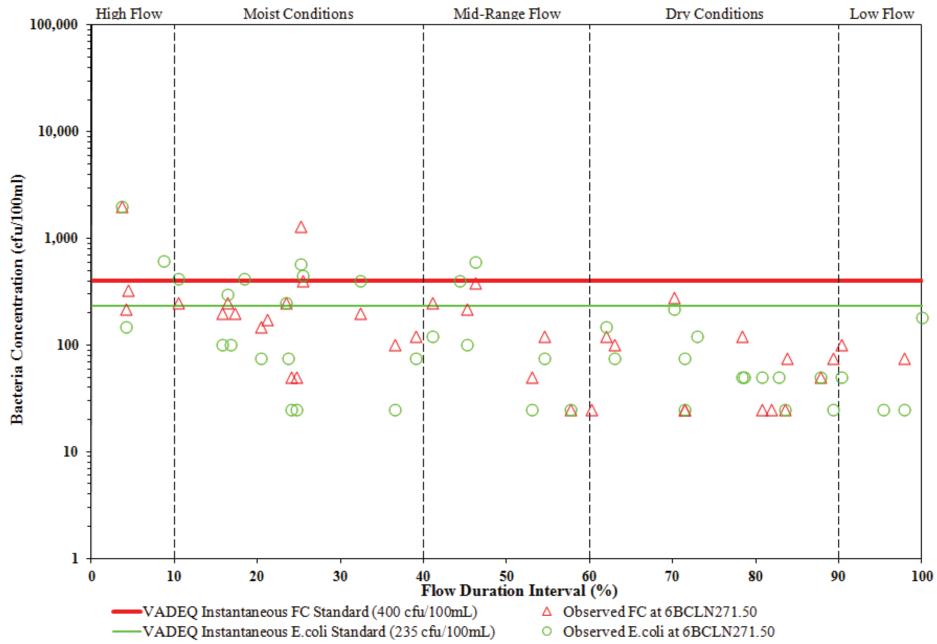

Figure C.4 Fecal and *E. coli* bacteria concentrations at 6BCLN271.50 on the Middle Clinch River versus discharge at USGS Gaging Station # 03524000.

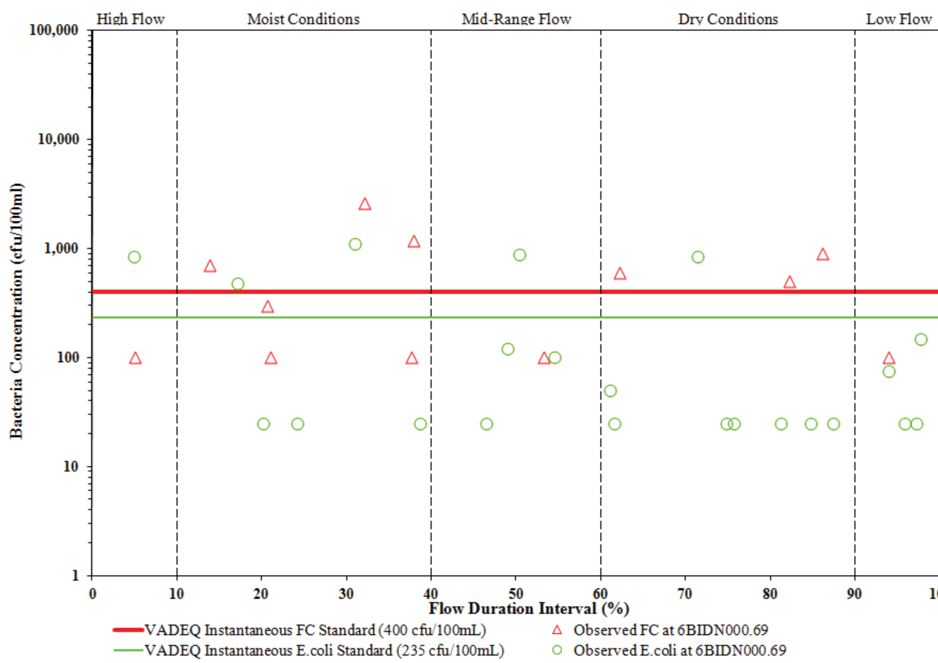

Figure C.5 Fecal and *E. coli* bacteria concentrations at 6BIDN000.69 on Indian Creek versus discharge at USGS Gaging Station # 03524000.

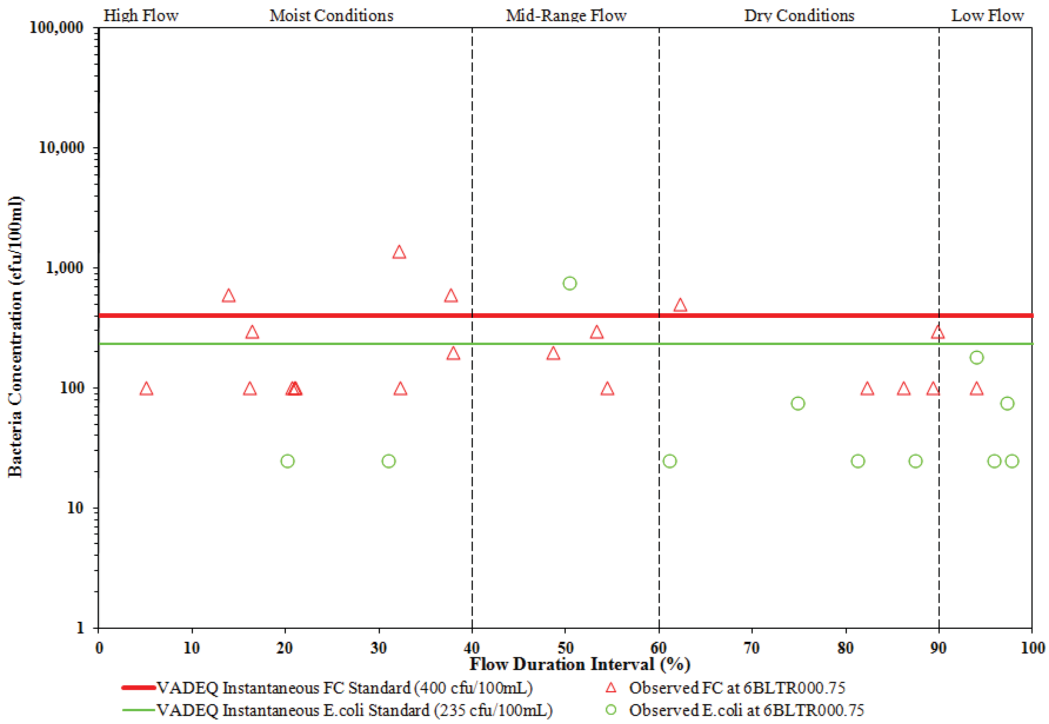

Figure C.6 Fecal and *E. coli* bacteria concentrations at 6BLTR000.75 on Little River versus discharge at USGS Gaging Station # 03524000.

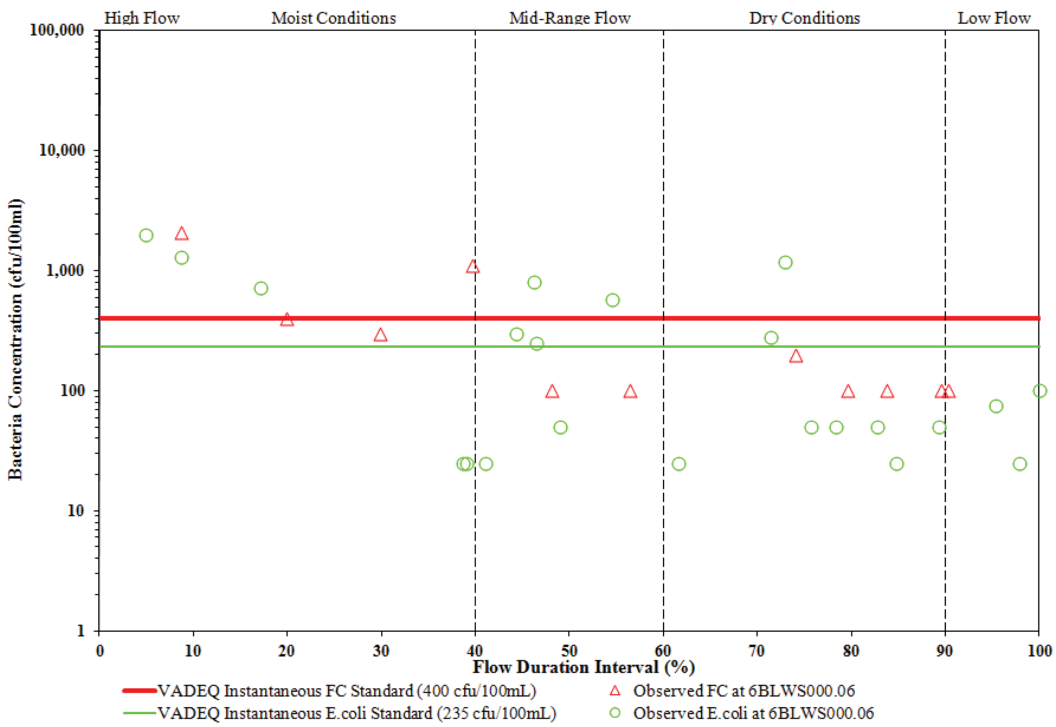

Figure C.7 Fecal and *E. coli* bacteria concentrations at 6BLWS000.06 on Lewis Creek versus discharge at USGS Gaging Station # 03524000.

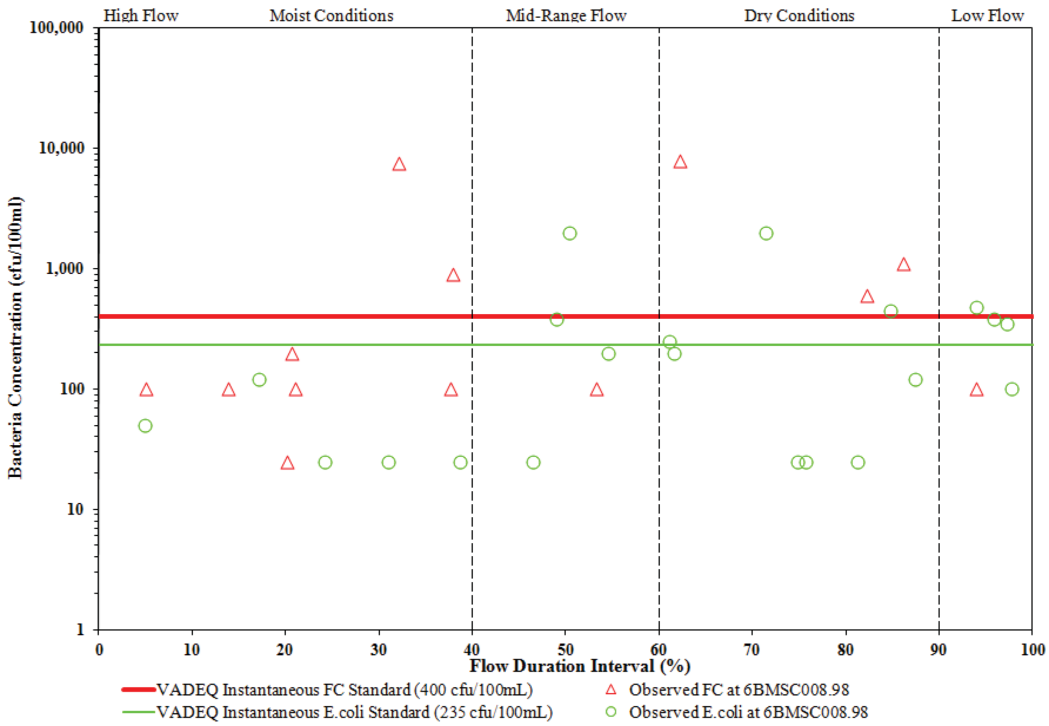

Figure C.8 Fecal and *E. coli* bacteria concentrations at 6BMSC008.98 on Maiden Springs Creek versus discharge at USGS Gaging Station # 03524000.

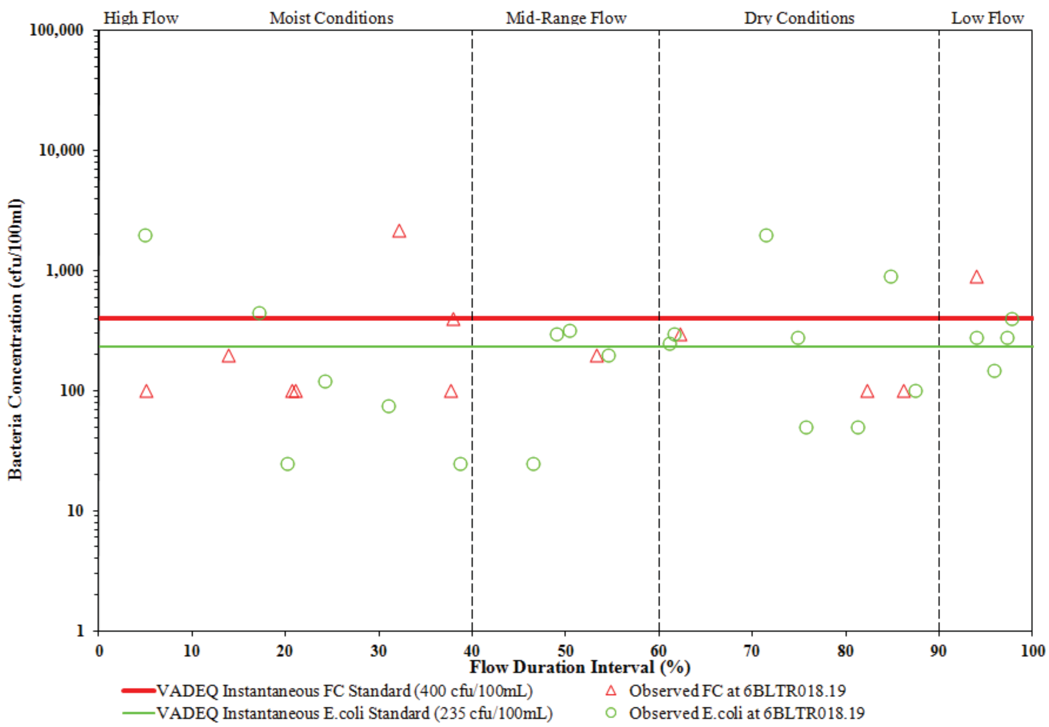

Figure C.9 Fecal and *E. coli* bacteria concentrations at 6BLTR018.19 on Little River versus discharge at USGS Gaging Station # 03524000.

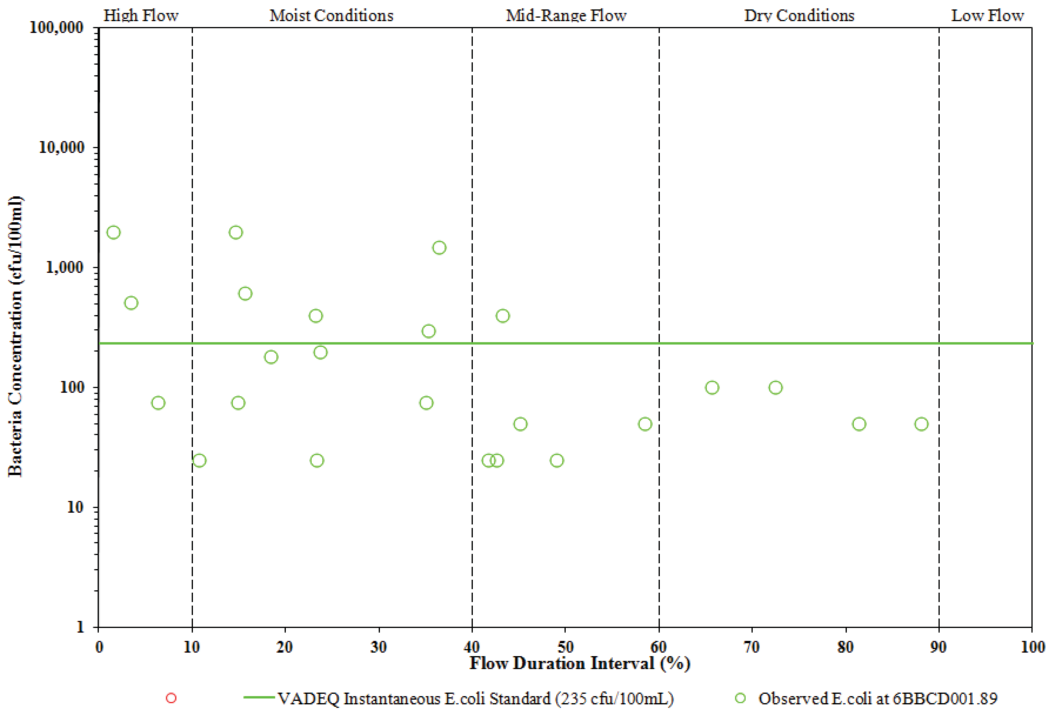

Figure C.10 ***E. coli*** **bacteria concentrations at 6BBCD001.89 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.**

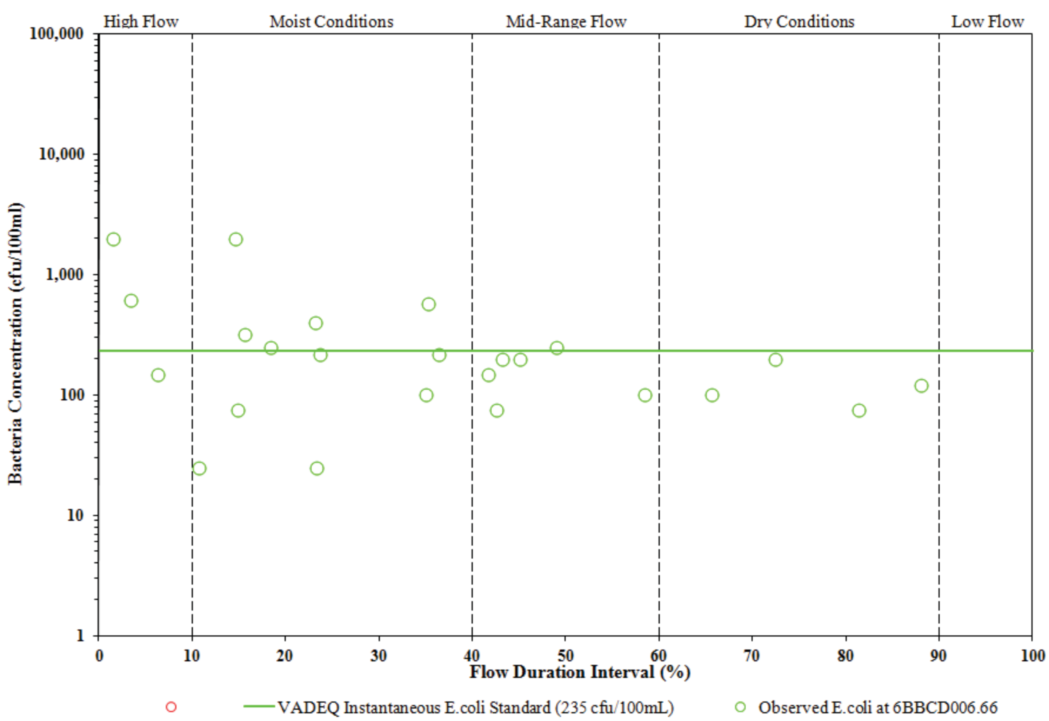

Figure C.11 ***E. coli*** **bacteria concentrations at 6BBCD006.66 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.**

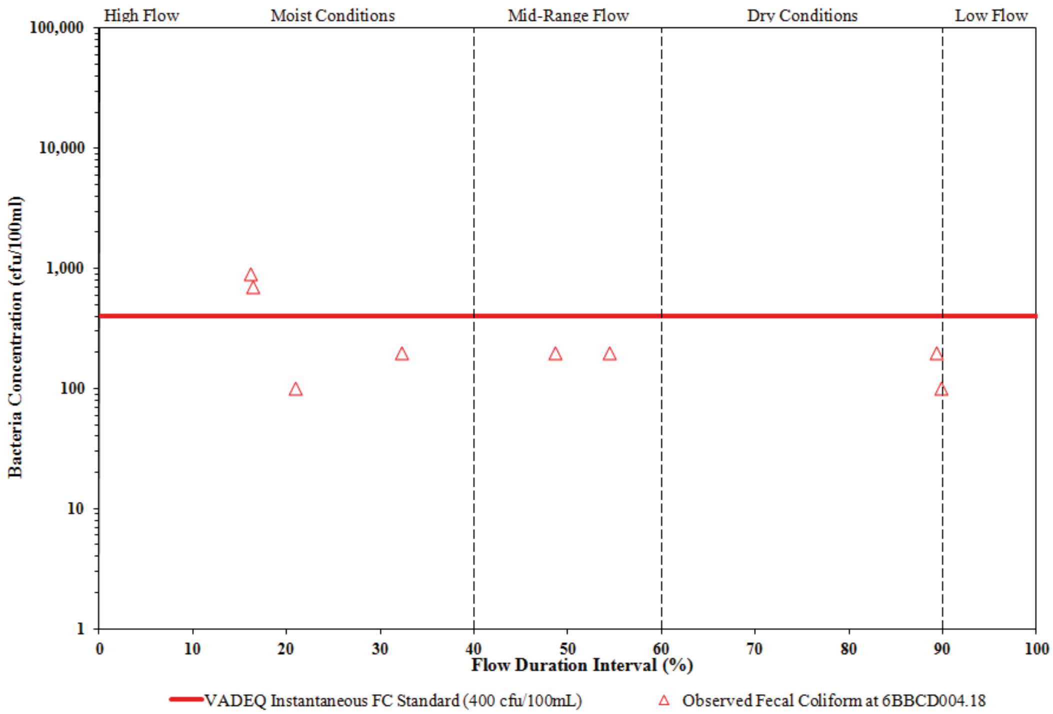

Figure C.12 Fecal bacteria concentrations at 6BBCD004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.

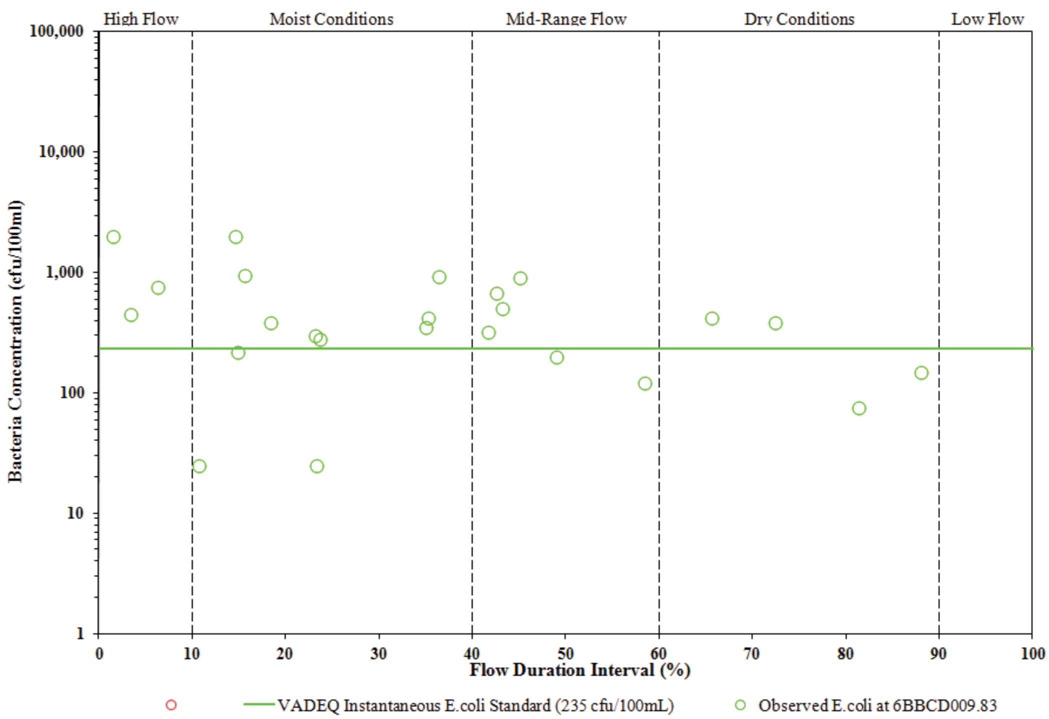

Figure C.13 *E. coli* bacteria concentrations at 6BBCD009.83 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.

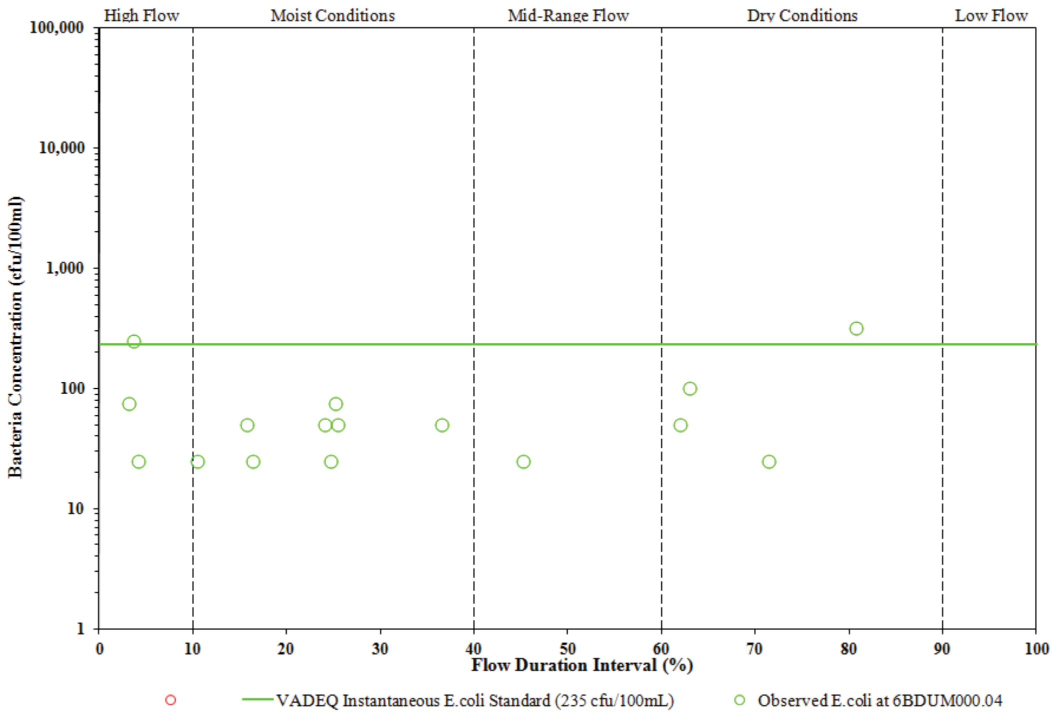

Figure C.14 ***E. coli*** **bacteria concentrations at 6BDUM000.04 on the Dumps Creek versus discharge at USGS Gaging Station # 03524000.**

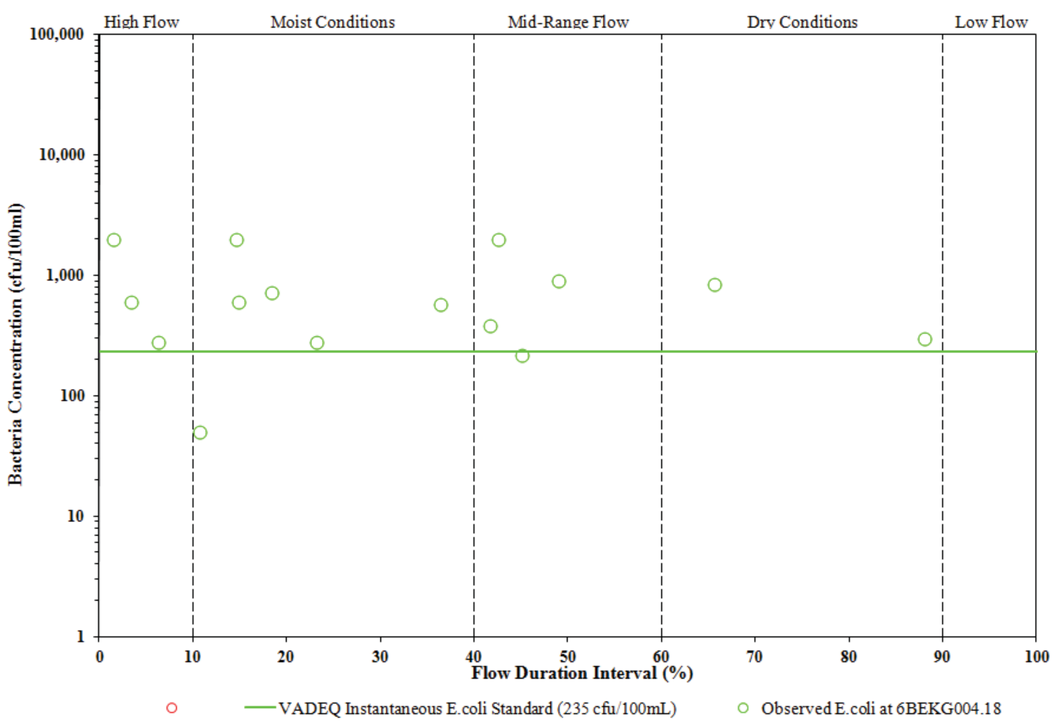

Figure C.15 ***E. coli*** **bacteria concentrations at 6BEKG004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.**

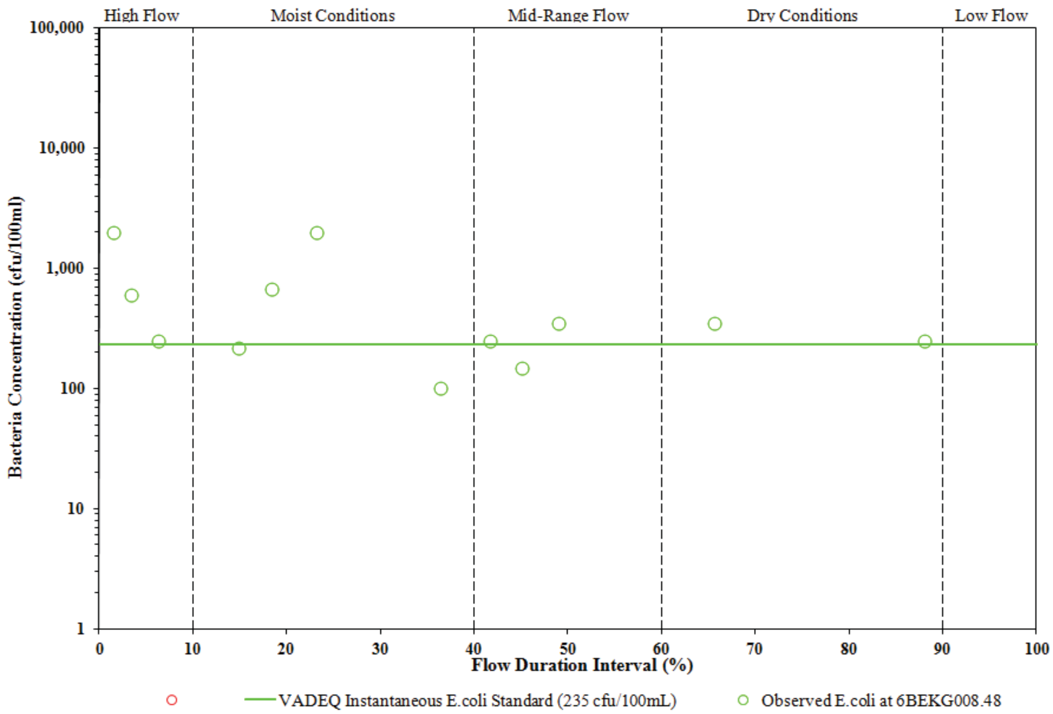

Figure C.16 ***E. coli*** **bacteria concentrations at 6BEKG008.48 on Elk Garden Creek versus discharge at USGS Gaging Station # 03524000.**

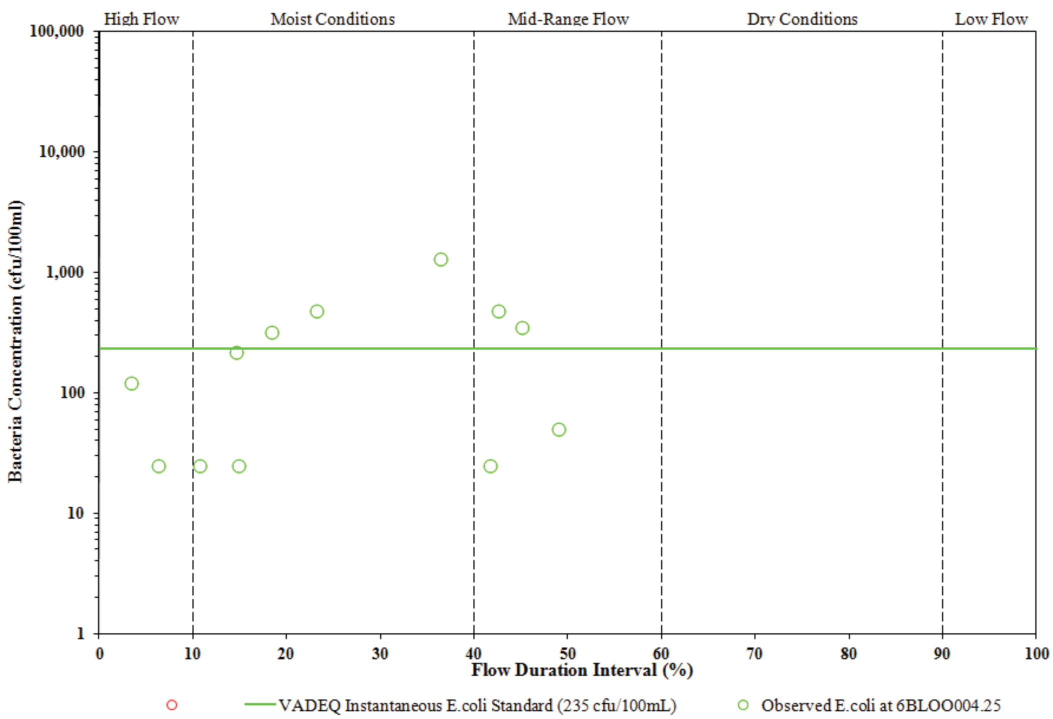

Figure C.17 ***E. coli*** **bacteria concentrations at 6BLOO004.25 on Loop Creek versus discharge at USGS Gaging Station # 03524000.**

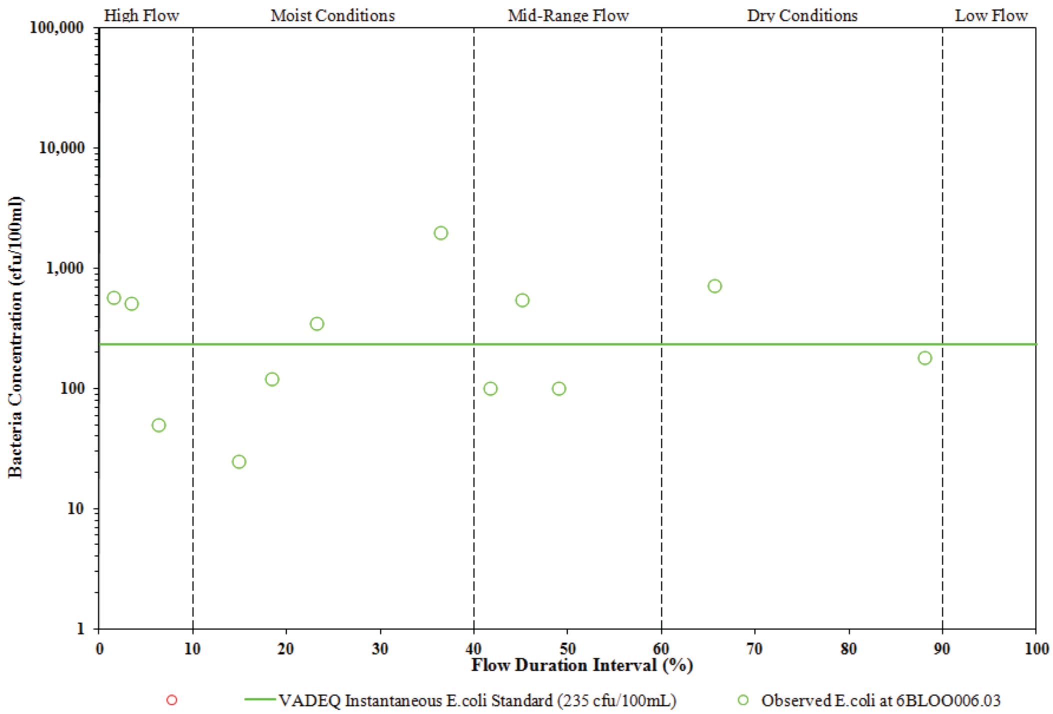

Figure C.18 ***E. coli* bacteria concentrations at 6BLOO006.03 on Loop Creek watershed versus discharge at USGS Gaging Station # 03524000.**

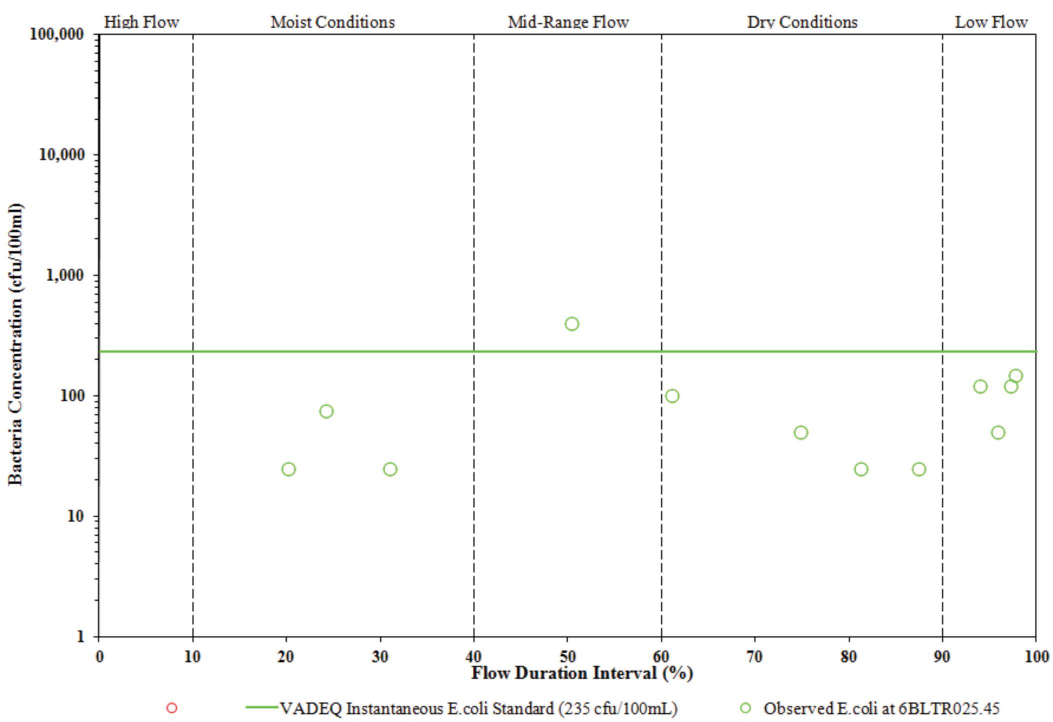

Figure C.19 ***E. coli* bacteria concentrations at 6BLTR025.45 on Little River versus discharge at USGS Gaging Station # 03524000.**

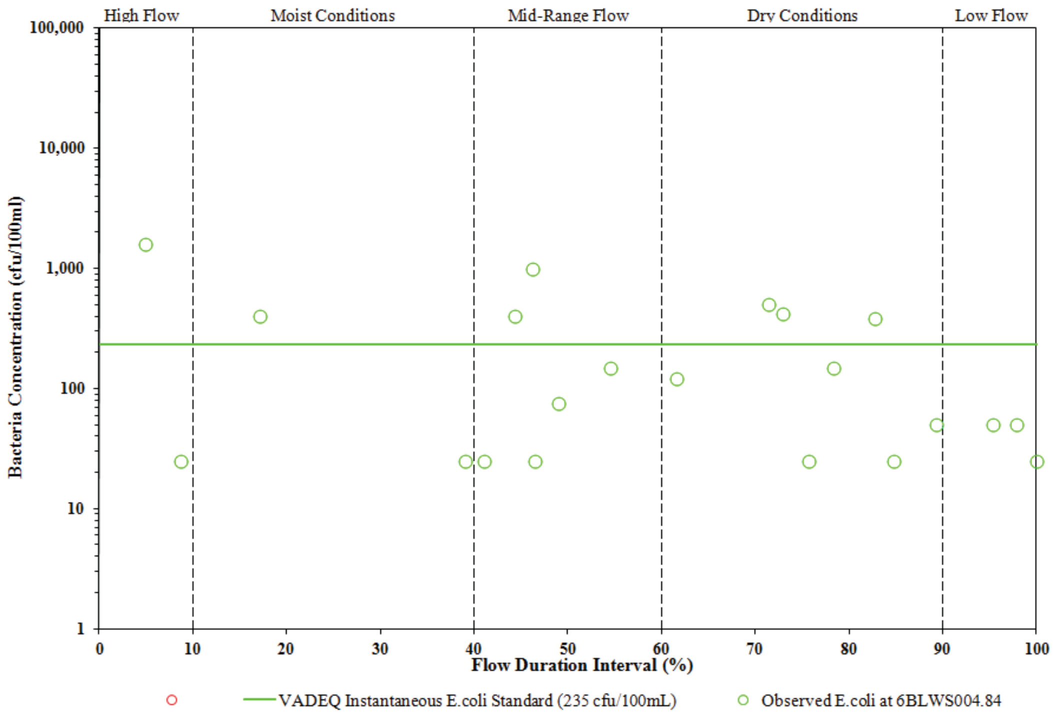

Figure C.20 ***E. coli*** **bacteria concentrations at 6BLWS004.84 on the Lewis Creek versus discharge at USGS Gaging Station # 03524000.**

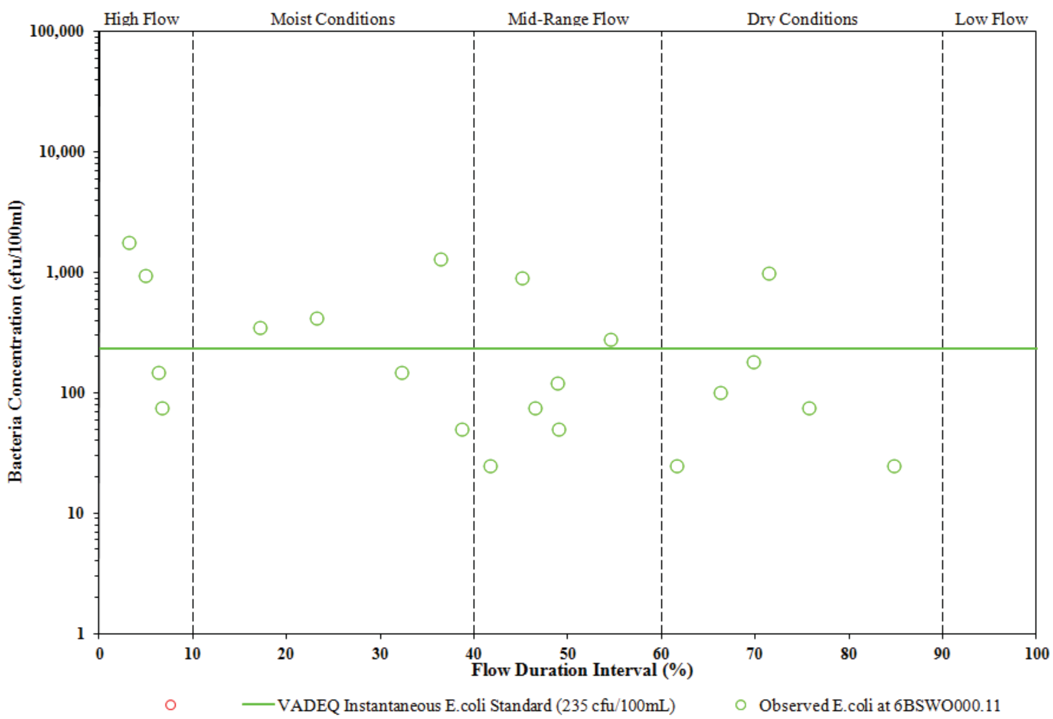

Figure C.21 ***E. coli*** **bacteria concentrations at 6BSWO000.11 on Swords Creek versus discharge at USGS Gaging Station # 03524000.**

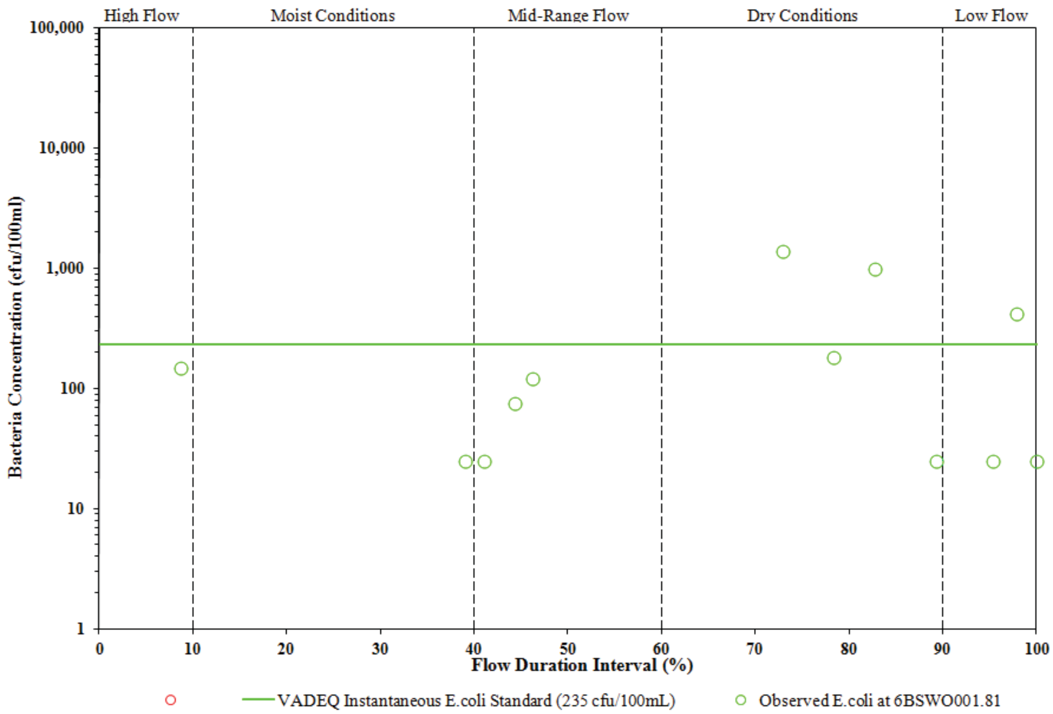

Figure C.22 ***E. coli*** **bacteria concentrations at 6BSWO001.81 on Swords Creek versus discharge at USGS Gaging Station # 03524000.**

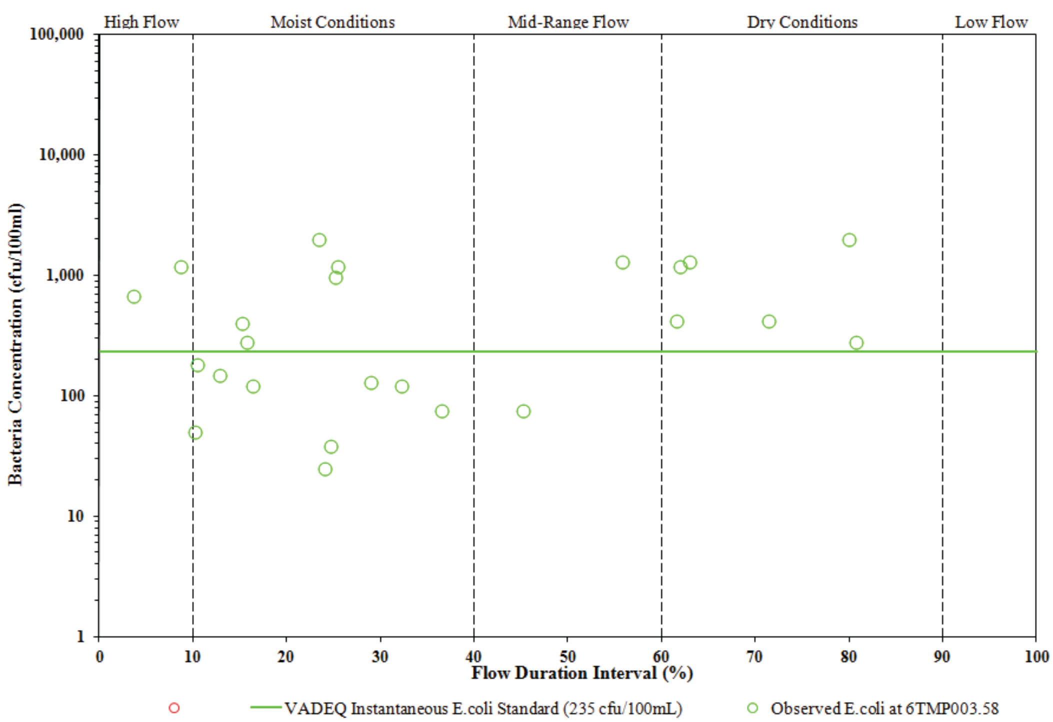

Figure C.23 ***E. coli*** **bacteria concentrations at 6BTMP003.58 on Thompson Creek versus discharge at USGS Gaging Station # 03524000.**

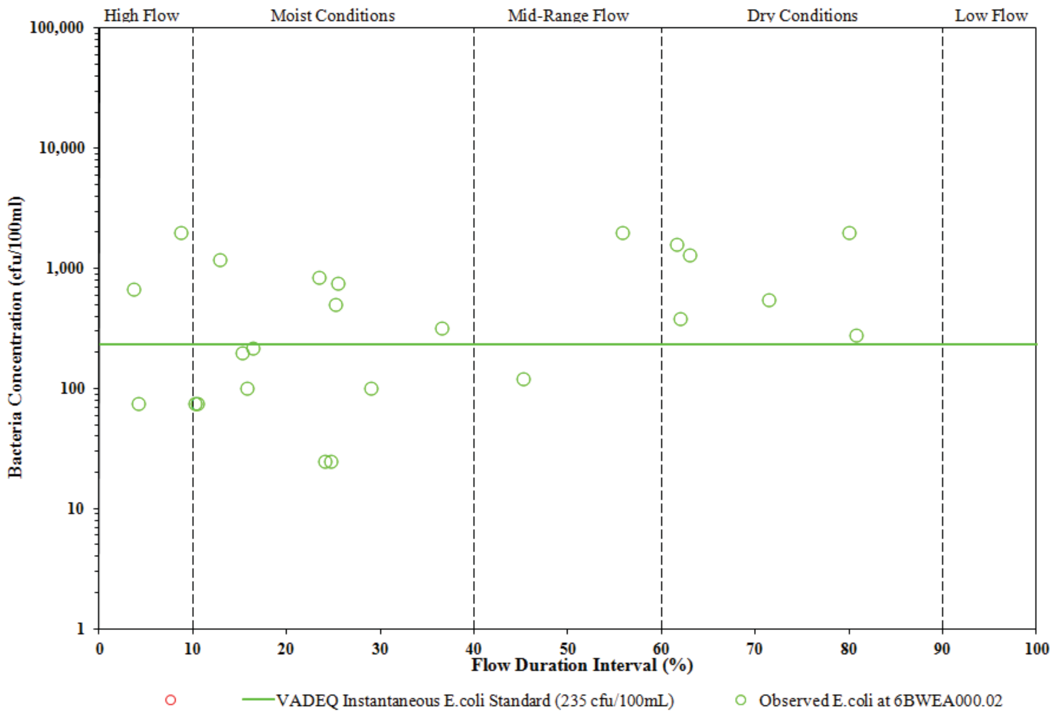

Figure C.24 ***E. coli*** **bacteria concentrations at 6BWEA000.02 on the Weaver Creek versus discharge at USGS Gaging Station # 03524000.**

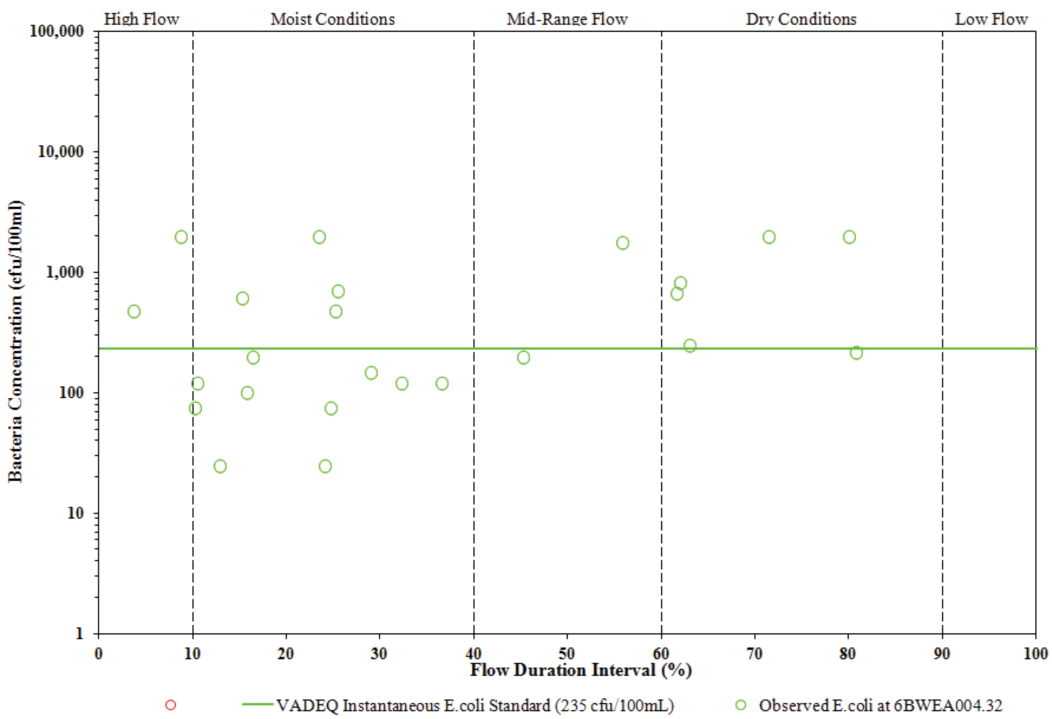

Figure C.25 ***E. coli*** **bacteria concentrations at 6BWEA004.32 on Weaver Creek versus discharge at USGS Gaging Station # 03524000.**

Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area.

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 03524000 in the Clinch River at Cleveland was available from October 1920 to the present. The Hydrologic calibration period was October 1988 to September 1991 and hydrologic validation period was October 2000 to September 2003. The fecal concentration data were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons. Multiple periods were used for water quality calibration and validation depending on the availability of monitored data.

The critical flow regime study showed that all flow regimes, but most critically high flows, should be represented in the modeling time periods of the impaired streams in this study. The hydrology calibration/validation/water quality calibration and validation time period, has both the high and low daily average streamflow at USGS Gaging Station #03524000 located at Cleveland and precipitation, which represent the high and low flow critical regimes (Figures C.26 and C.27). The figures are shown here to demonstrate the historical annual and seasonal stream flow and precipitation and how the selected time period encompasses a representative range of values. Table C.6 shows the statistical comparison between calibration/validation time periods and historic time period.

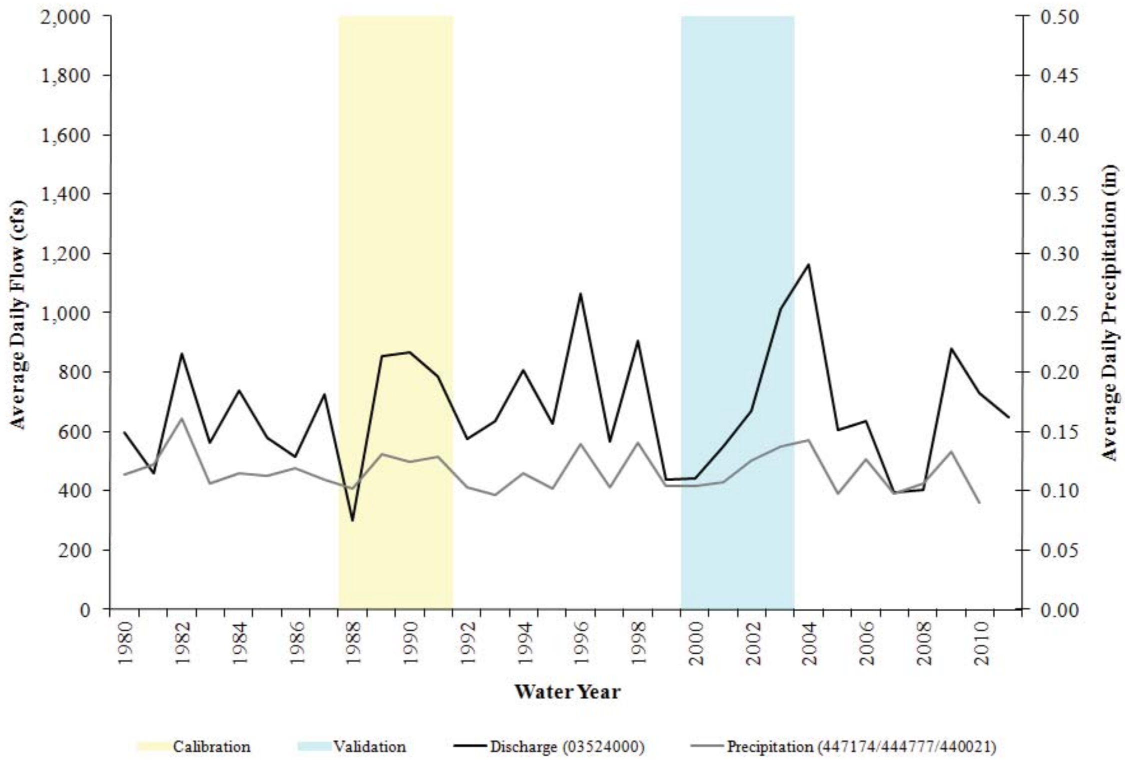

Figure C.26 Modeling time periods, annual historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data.

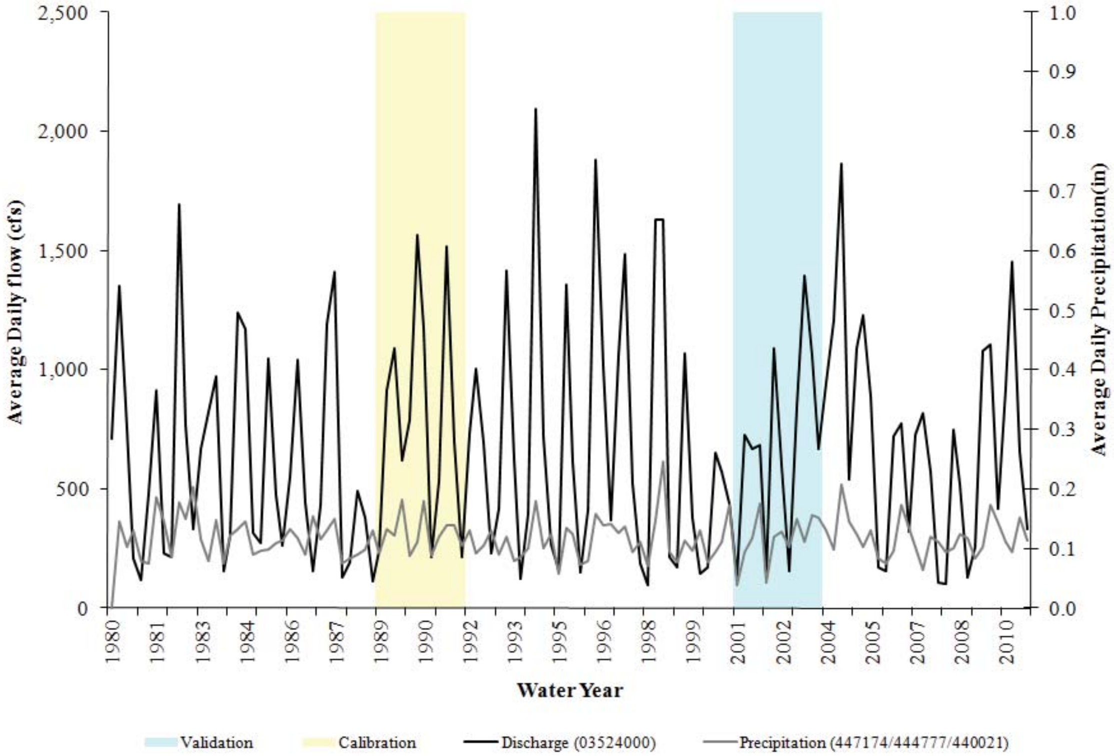

Figure C.27 Modeling time periods, seasonal historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data.

Table C.6 Comparison of modeled period to historical records for the Clinch River.

	Discharge (03524000)				Precipitation (447174/444777/440021)			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1921 - 2011)				**Historical Record (1970 - 2010)**			
Mean	480	1,288	777	293	0.102	0.120	0.138	0.128
Variance	102,320	204,811	97,896	30,051	0.001	0.001	0.001	0.001
	Calibration and Validation Time Periods (10/88-9/91; 10/00-9/03)				**Calibration and Validation Time Periods (10/88-9/91; 10/00-9/03)**			
Mean	438	1,261	866	291	0.093	0.125	0.141	0.126
Variance	135,939	145,032	199,019	30,314	0.000	0.0004	0.003	0.001
	p-values				**p-values**			
Mean	0.385	0.430	0.302	0.487	0.185	0.285	0.436	0.451
Variance	0.253	0.356	0.069	0.425	0.269	0.090	0.041	0.279

Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.,* animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.,* population). Depending on the timeframe of the simulation being run, different estimates were used. Data were obtained for the appropriate timeframe for water quality calibration and validation. Data representing 2010 were used for the allocation runs in order to represent current conditions.

Forty nine (49) point sources are permitted to discharge water into surface waters in the Upper Clinch River Watershed study area through the Virginia Pollutant Discharge Elimination System (VPDES) (Tables 3.1 and 3.2). Section 3.2 discusses these permits in more detail. Forty five (45) of the VPDES permits are domestic or single family home permits that discharge less than 1,000 gallons per day. For calibration and validation condition runs, recorded flow and fecal bacteria concentration or Total Residual Chlorine (TRC) levels documented by the VADEQ were used as the input for each permit. The TRC data was related to fecal bacteria concentrations using a regression analysis. Table C.7 shows the minimum and maximum discharge rate in million gallons per day (MGD) and the minimum and maximum fecal coliform bacteria concentration in colony forming units per 100 milliliters (cfu/100mL). These values are the sums of all the data for each outfall.

The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu per 100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. The design flow rates and fecal coliform bacteria concentrations are shown in Table C.7.

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

Table C.7 Flow rates and bacteria loads used to model VADEQ active permits in the Middle Clinch River watershed study area.

		Calibration/Validation				Allocation	
		Flow Rate (MGD)		Bacteria Concentration (cfu/100mL)		Flow Rate (MGD)	Bacteria Concentration (cfu/100mL)
VADEQ Permit Number	Facility Name	Min	Max	Min	Max	Design Flow	Fecal Coliform Geometric Mean Standard
VA0020672	DOC - Appalachian Detention Center 29	0.006	0.012	3.39	4.89	0.021	200
VA0020745	Lebanon WWTP	0.257	0.864	3.79	8.18	0.999	200
VA0026387	Honaker STP	0.069	1.460	0.00	125.18	0.400	200
VA0064271	Claypool Hill STP	0.086	0.376	2.79	4.28	0.350	200
VAG******	Each of the 45 Domestic Waste Treatment Permits	0.001	0.001	200	200	0.001	200

The number of septic systems in the Middle Clinch River watershed study area was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the subwatersheds. During allocation runs, the number of households was projected to 2011, based on current growth rates (USCB, 2000) resulting in 9,472 septic systems and 44 straight pipes (Table C.8).

Table C.8 Estimated failing septic systems and straight pipes for 2011 in the Middle Clinch River watershed study area.

Subwatershed*	Septic Systems	Failing Septic Systems	Straight Pipes
1	860	29	6
2	212	7	2
3	151	5	0
4	258	9	1
5	128	4	1
7	139	5	1
8	166	6	1
9	1,640	55	3
10	890	30	1
11	157	5	0
12	364	12	1
13	652	22	1
14	457	15	2
15	579	19	1
16	810	27	4
17	703	23	6
18	384	13	3
Total	**9,472**	**316**	**44**

*Subwatershed 6 (Upper Clinch River watershed) was included in a previously approved TMDL.

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDL for the Middle Clinch River watershed study area. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

Straight pipes were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category "other means" were assumed to be disposing sewage via straight pipes. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from straight pipes were modeled in the same manner as direct discharges to the stream.

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Different livestock populations were estimated for each water quality modeling period (calibration/validation/allocation). The numbers are based on data provided by Virginia Agricultural Statistics (VASS), with values updated and discussed by VADCR, NRCS and SWCDs as well as taking into account growth rates in these counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1997; VASS, 2002). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse, sheep, goats) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land was area-weighted.

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

Investigation of VADEQ data indicated that biosolids applications have not occurred within the Middle Clinch River watershed study area during the modeling periods.

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in Figure C.28. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.

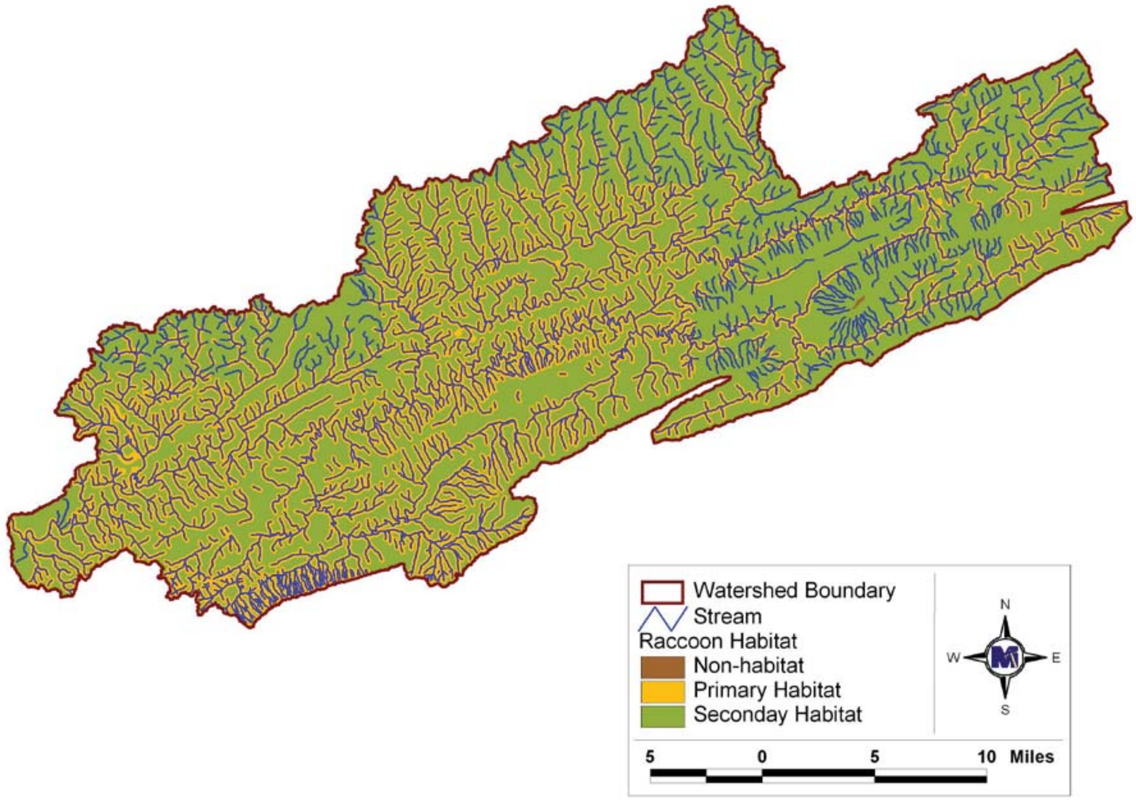

Figure C.28 Example of raccoon habitat layer in the Middle Clinch River watershed study area, as developed by MapTech.

For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.13). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2011.

Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), groundwater recession flow (KVARY), and active groundwater storage PET (AGWETP). Table C.9 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

Table C.9 Initial hydrologic parameters estimated for the Middle Clinch River watershed TMDL study area, and resulting final values after calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Final Calibrated Parameter Value
LZSN	in	2.0 – 15.0	7.0	5.0
INFILT	in/hr	0.001 – 0.50	0.08 – 0.202	0.048 – 0.121
KVARY	1/in	0.0 – 5.0	1.5	4.5
AGWRC	1/day	0.85 – 0.999	0.955	0.98
DEEPFR	---	0.0 – 0.50	0.01 – 0.02	0.01 – 0.02
BASETP	---	0.0 – 0.20	0 – 0.01	0.05
AGWETP	---	0.0 – 0.20	0 – 0.01	0 – 0.01
INTFW	---	1.0 – 10.0	1.0	3
IRC	1/day	0.30 – 0.85	0.6	0.3
MON-INTERCEPT	in	0.01 – 0.40	0 – 0.2	0 – 0.40
MON-UZSN	in	0.05 – 2.0	0.5 – 1.93	0.25 – 1.93
MON-LZETP	---	0.1 – 0.9	0 – 0.8	0 – 0.9

Table C.10 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated. Figures C.12 and C.13 graphically show these comparisons.

Table C.10 Hydrology calibration model performance from 10/1/1988 through 9/30/1991 at USGS Gaging Station # 03524000 on the Clinch River (subwatershed 19).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	53.84	49.52	-8.04%
Upper 10% Flow Values:	19.34	17.17	-11.25%
Lower 50% Flow Values:	9.15	8.66	-5.39%
Winter Flow Volume	22.27	19.01	-14.65%
Spring Flow Volume	16.68	14.48	-13.20%
Summer Flow Volume	5.97	5.87	-1.79%
Fall Flow Volume	8.92	10.16	13.95%
Total Storm Volume	47.03	44.09	-6.26%
Winter Storm Volume	20.59	17.67	-14.18%
Spring Storm Volume	14.97	13.12	-12.39%
Summer Storm Volume	4.25	4.52	6.34%
Fall Storm Volume	7.22	8.79	21.60%

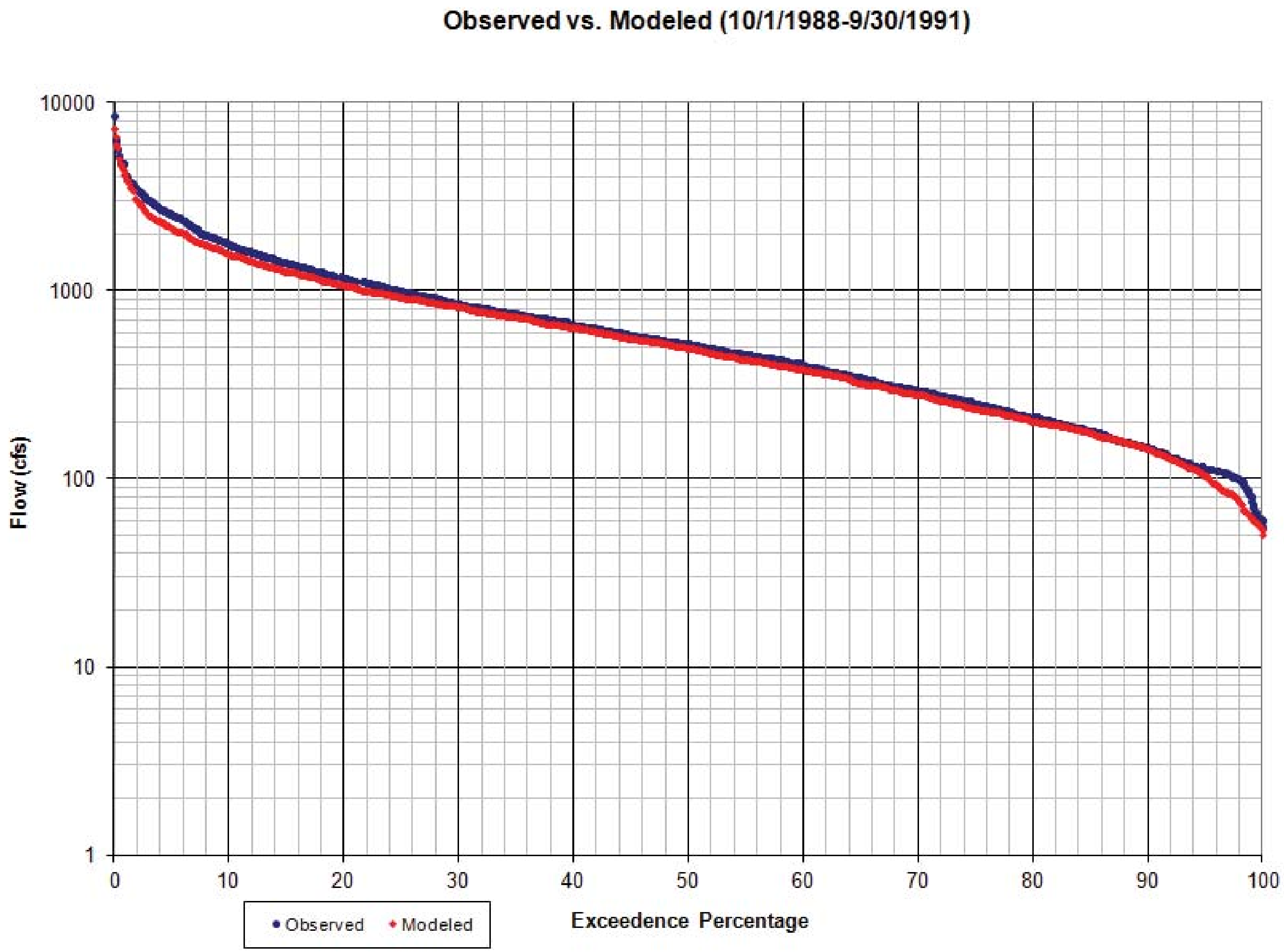

Figure C.29 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19).

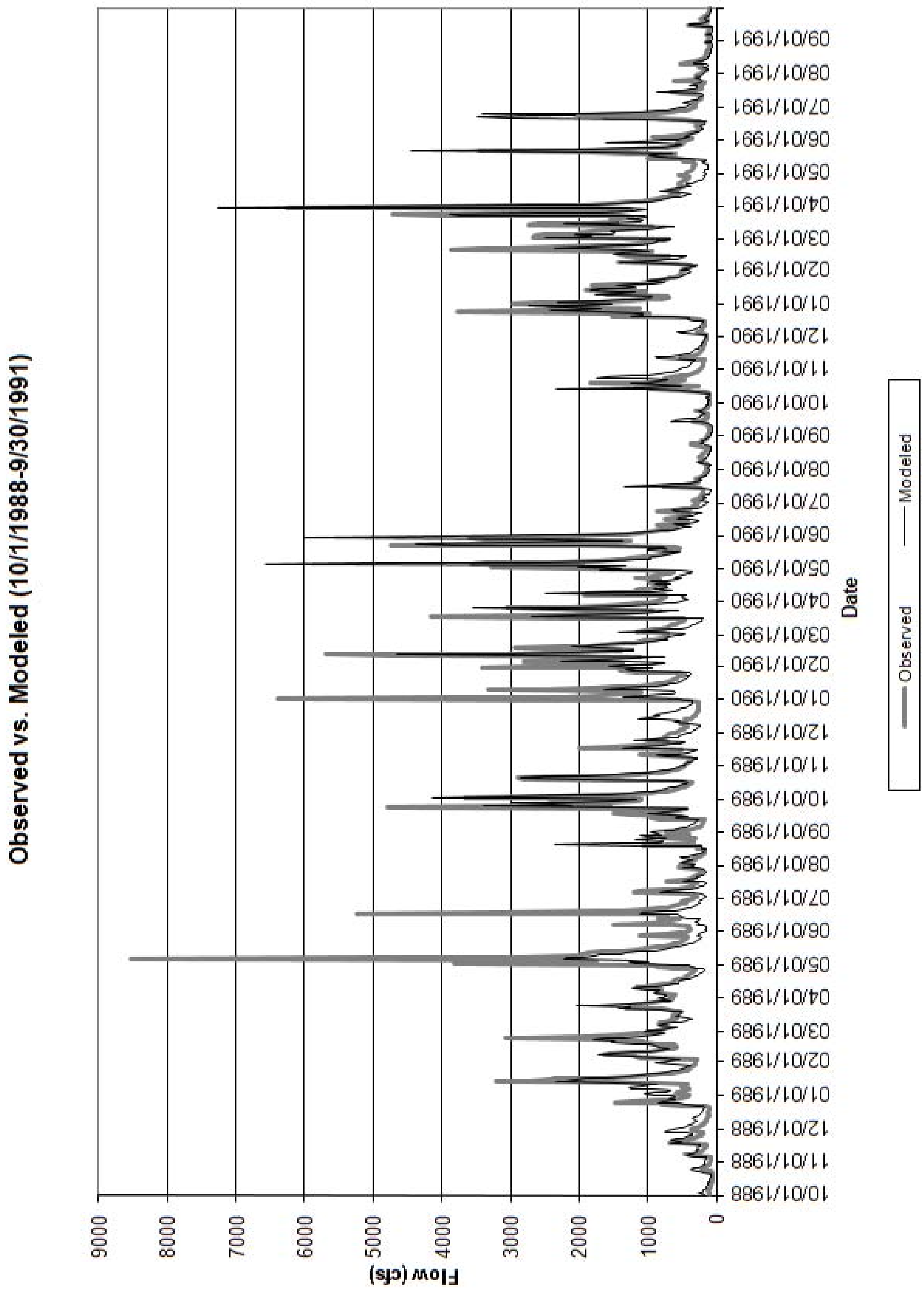

Figure C.30 Clinch River modeled results versus USGS Gaging Station # 03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19).

The modeled output was validated for the period of 10/1/2000 to 9/30/2003. Simulated flow at subwatershed 19 was compared with daily flow at the Clinch River USGS Gaging Station #03524000. Table C.11 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated and has been validated during a different time period. Figures C.14 and C.15 graphically show these comparisons.

Table C.11 Hydrology validation model performance from 10/1/2000 through 9/30/2003 at USGS Gaging Station #03524000 on the Clinch River (subwatershed 19).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	45.86	42.41	-7.51%
Upper 10% Flow Values:	21.01	18.49	-11.97%
Lower 50% Flow Values:	5.80	5.86	1.10%
Winter Flow Volume	17.87	14.50	-18.88%
Spring Flow Volume	13.09	10.25	-21.72%
Summer Flow Volume	8.58	9.62	12.13%
Fall Flow Volume	6.32	8.05	27.42%
Total Storm Volume	40.50	38.99	-3.72%
Winter Storm Volume	16.54	13.65	-17.49%
Spring Storm Volume	11.75	9.39	-20.06%
Summer Storm Volume	7.24	8.76	20.96%
Fall Storm Volume	4.96	7.19	44.92%

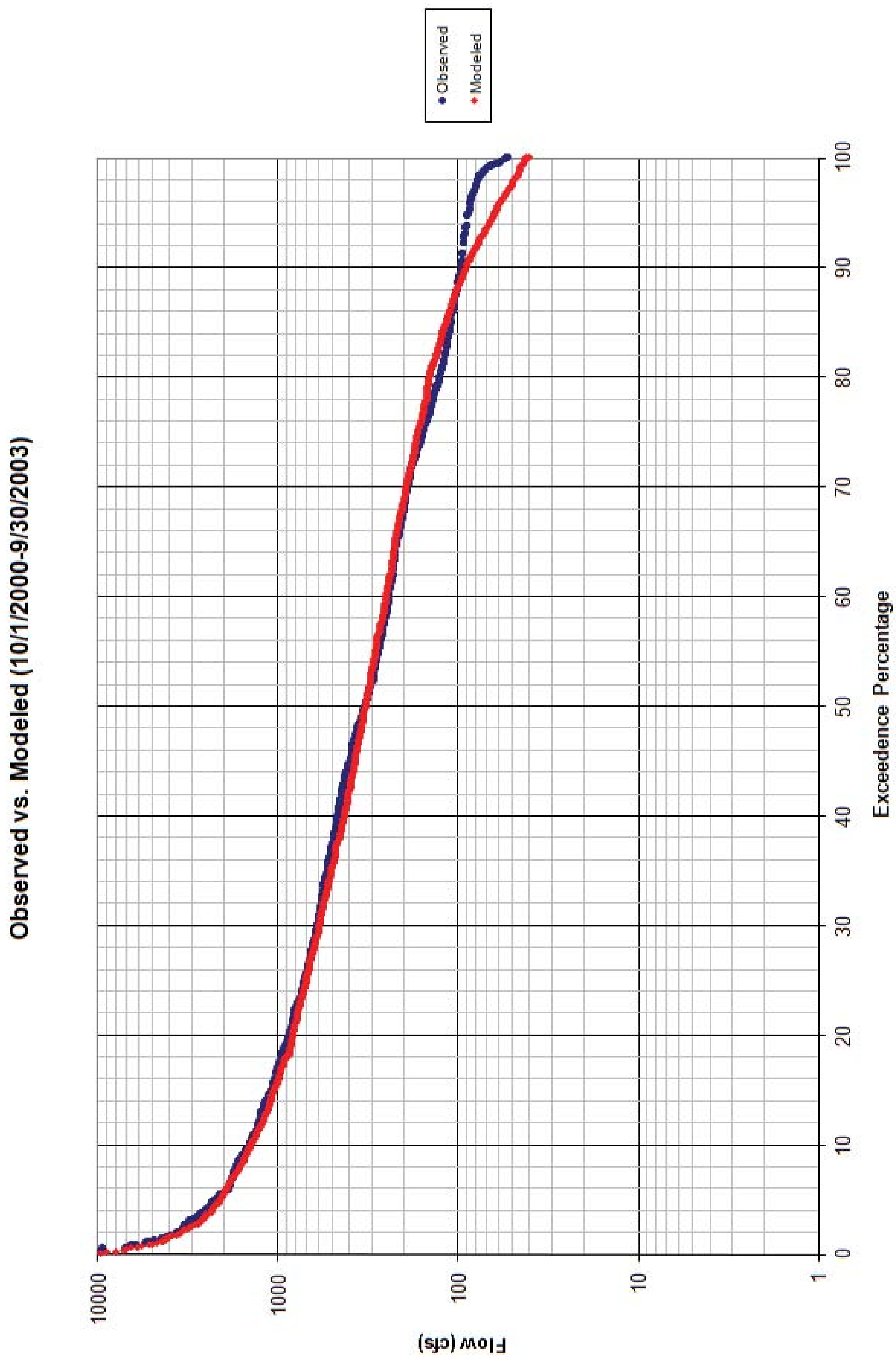

Figure C.31 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19).

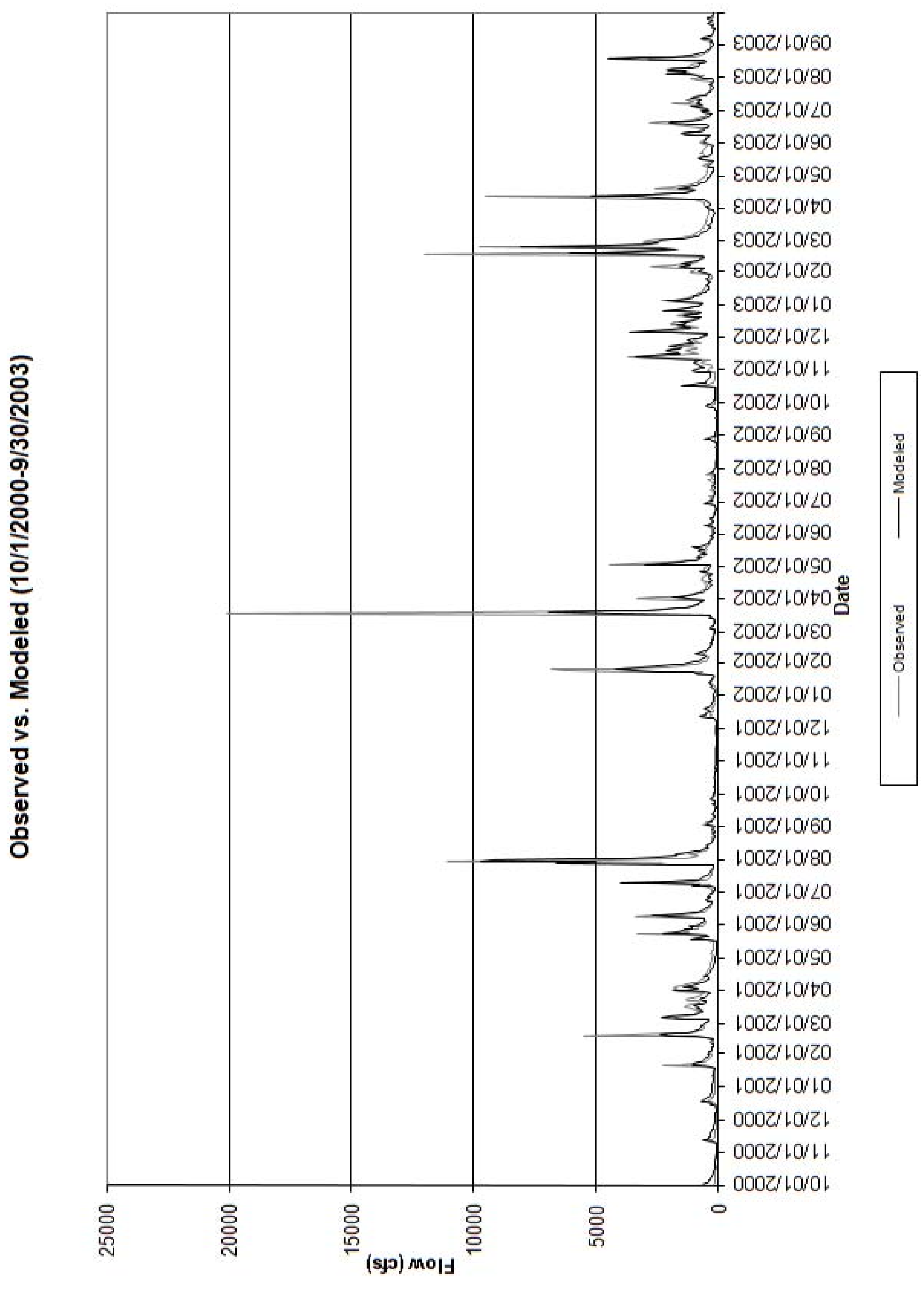

Figure C.32 Clinch River validation modeled results versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19).

Water quality calibration is complicated by a number of factors; first, water quality (*E. coli*) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of *E. coli* is particularly variable. Variability in location and timing of fecal deposition, variability in the density of bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling *E. coli* concentrations. Additionally, the VADEQ data were censored at specific high and low values (e.g. 8,000 cfu/100ml or 16,000 cfu/100ml as highs or 100 cfu/100ml as low value). Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP), and the temperature correction coefficient for first-order decay of quality (THFST). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established. Depending on the type of available bacteria data, either fecal coliform or *E. coli* monitored data were used. Table C.12 shows the model parameters utilized in calibration with their typical ranges, initial estimates, and final calibrated values. Table C.13 shows the time period, the subwatershed which the station is located, and bacteria type used for each monitoring station used in the calibration.

Table C.12 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0 – 5.8E+12	0.0 – 5.8E+12
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.80	0 – 3
FSTDEC	1/day	0.01 – 10.00	1.0	1-10
THFST	none	1.0 – 2.0	1.07	1.07

Table C.13 Bacteria calibration periods, subwatersheds and streams containing stations, and type of bacteria used in the Clinch River watershed study area.

Station	Stream	Calibration Period	Subwatershed	Type of Bacteria Used
6BSWO001.81	Swords	10/1/2007 – 8/31/2010	17	E. Coli
6BLWS000.06	Lewis Creek	10/1/2007 – 8/31/2010	16	E. Coli
6BDUM000.04	Dumps Creek	10/1/2007 – 8/31/2010	7	E. Coli
6BEKG004.18	Elk Garden Creek	10/1/2007 – 8/31/2010	10	E. Coli
6BBCD001.89	Big Cedar Creek	10/1/2007 – 8/31/2010	9	E. Coli
6BCLN271.50	Clinch River	10/1/2007 – 8/31/2010	19	E. Coli

Figures C.34 and C.39 show the results of water quality calibration. Monitored values are an instantaneous snapshot of the bacteria level, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at the highest concentration of the day and thus correctly appear above the modeled daily average. Although the range of modeled daily average values may not reach every instantaneous monitored value, the modeled data follows the trend of monitored data, and typically includes the monitored extremes.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Table C.14 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Clinch River stream segments.

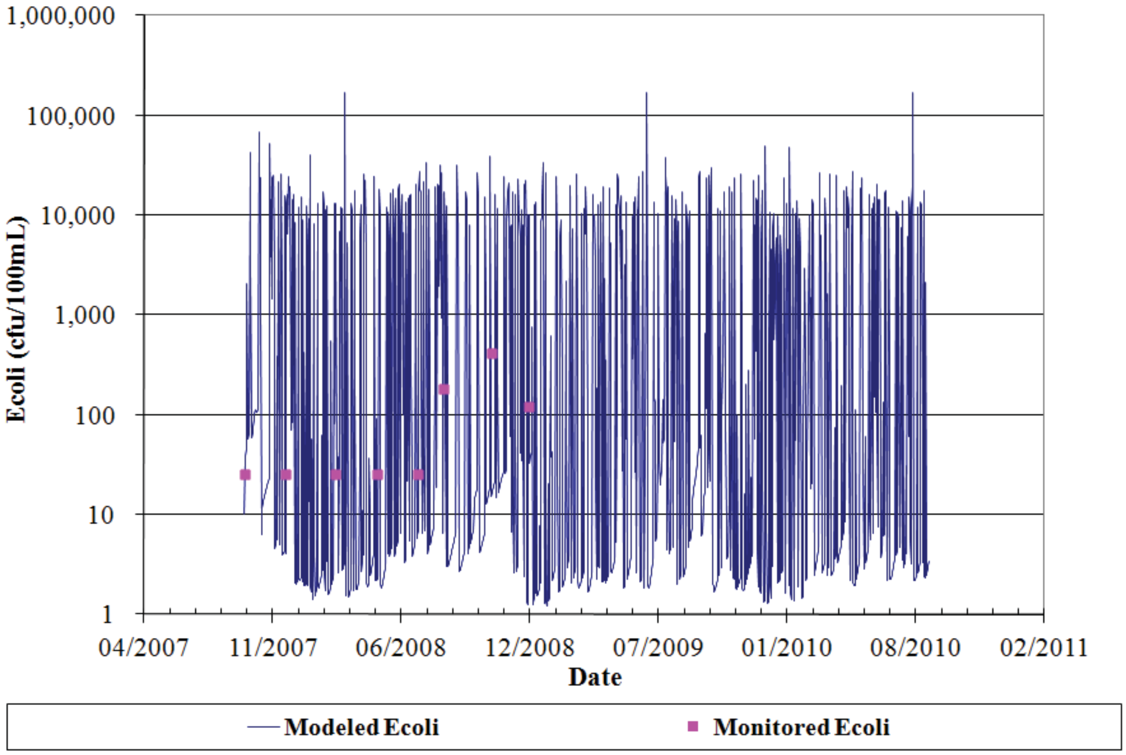

Figure C.34 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek.

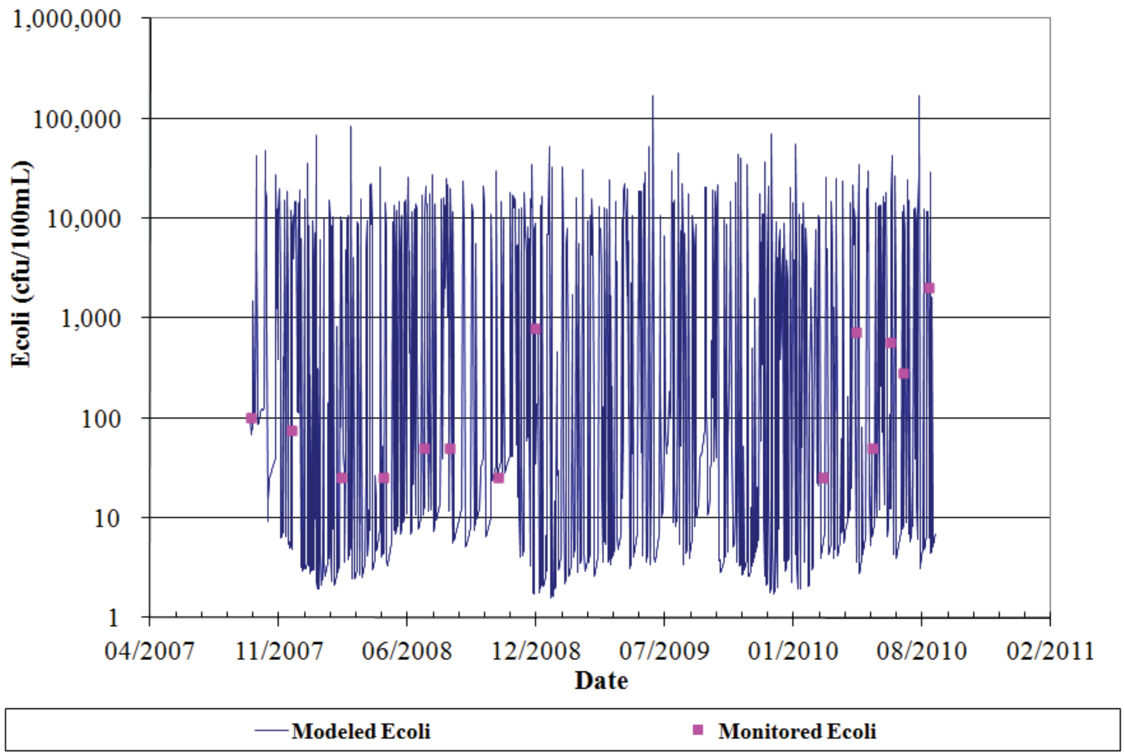

Figure C.35 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek.

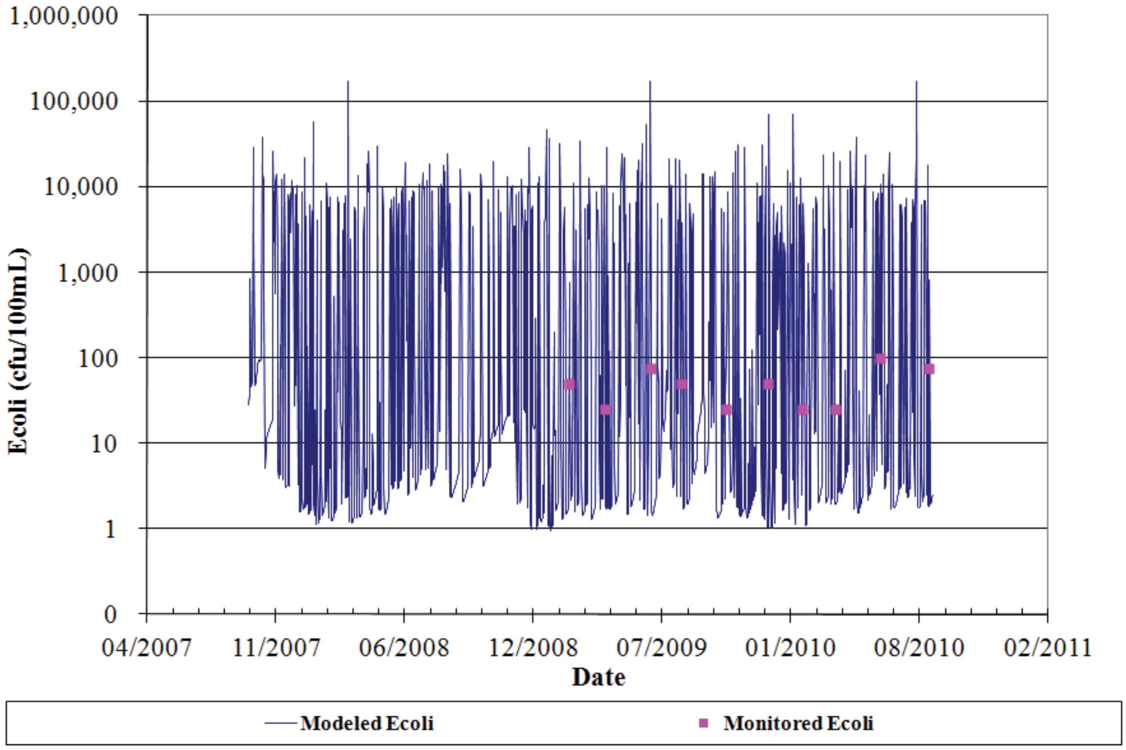

Figure C.36 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek.

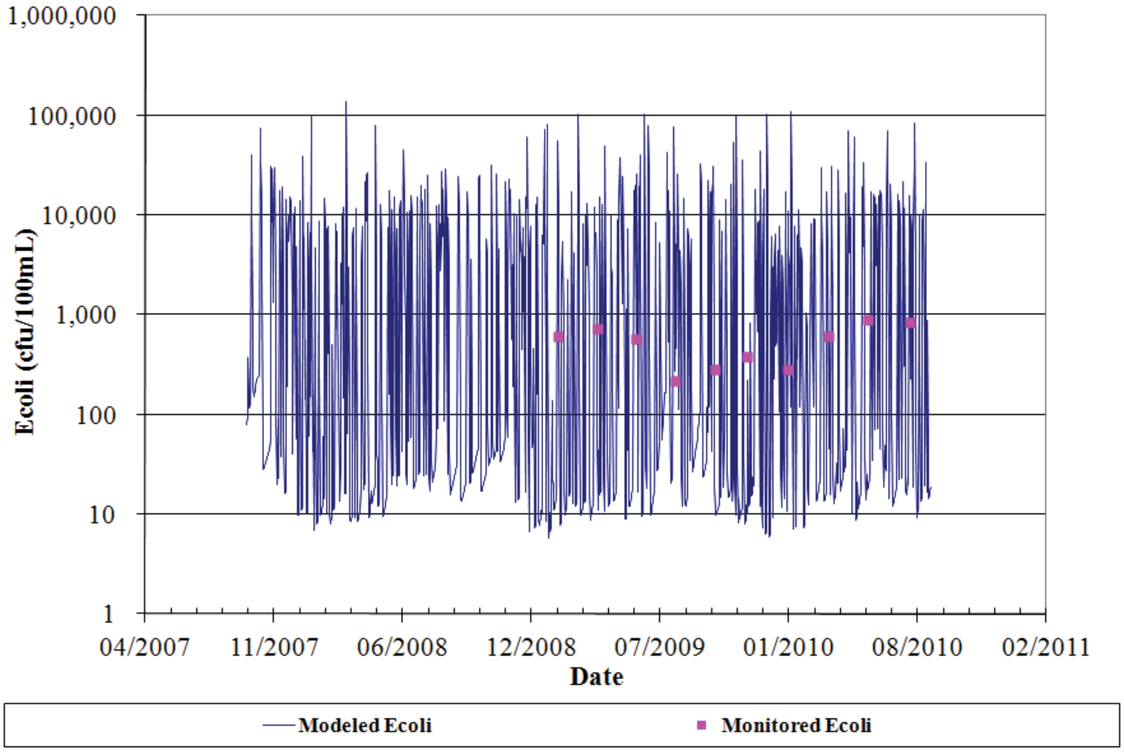

Figure C.37 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek.

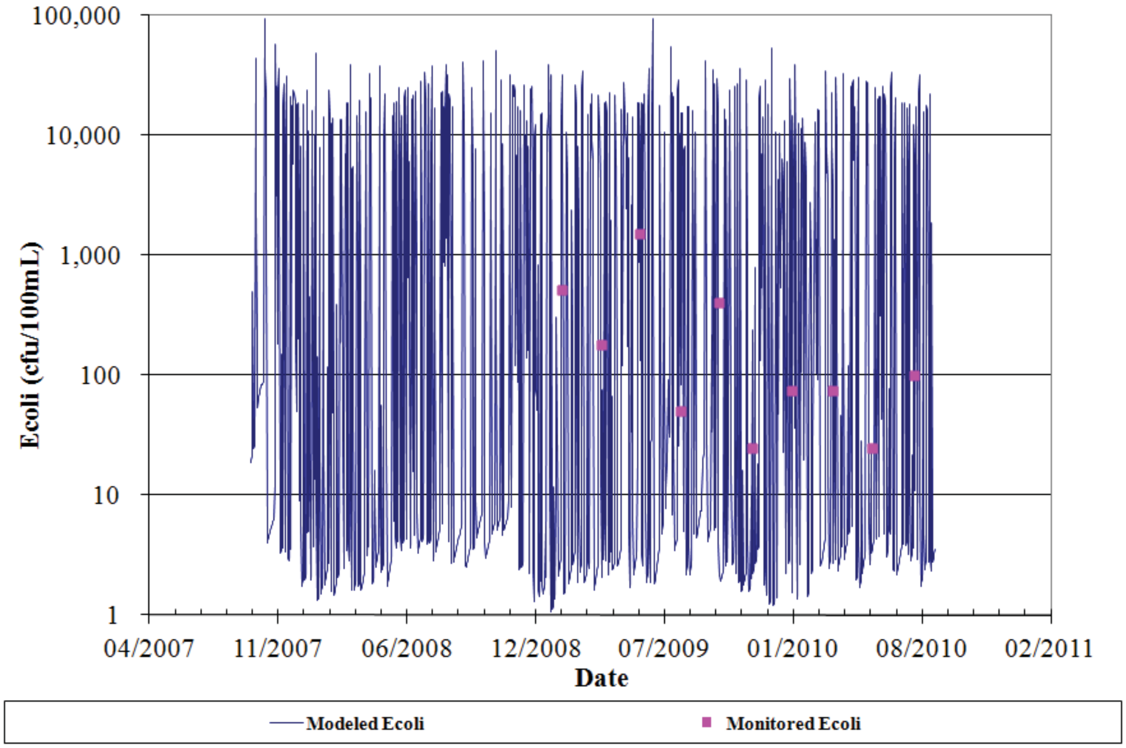

Figure C.38 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek.

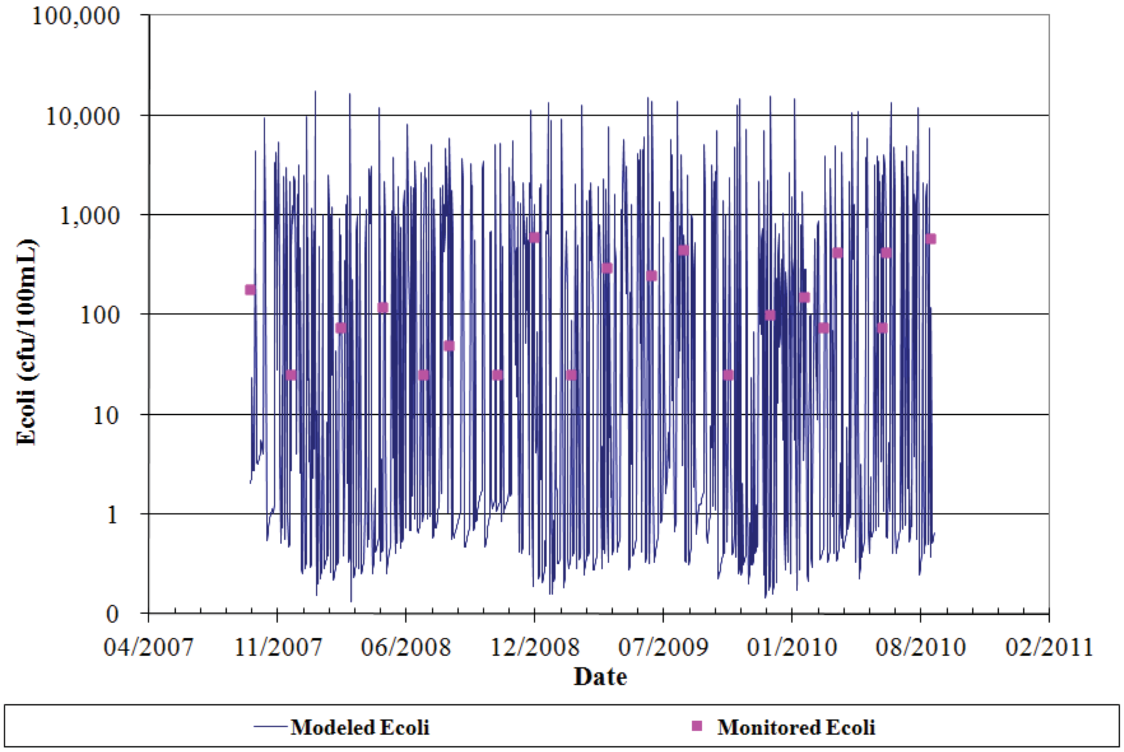

Figure C.39 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River.

Table C.14 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the calibration period.

Station	Subwatershed	Maximum Value (cfu/100ml)		Geometric Mean (cfu/100ml)		SS % violations [1]	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BSWO001.81	17	420	170,790	55.39	77.47	13%	35%
6BLWS000.06	16	2,000	170,790	108.55	100.69	33%	36%
6BDUM000.04	7	100	170,790	44.04	52.82	0%	34%
6BEKG004.18	10	900	136,790	487.22	254.99	90%	44%
6BBCD001.89	9	1,500	94,508	125.73	81.84	30%	37%
6BCLN271.50	19	600	17,309	114.03	110.64	35%	31%

[1] SS = single sample instantaneous standard violations (>235 cfu/100mL for E. coli)

Bacteria water quality model validation was performed on stations shown in Table C.15. Figures C.39 to C.44 shows the results of water quality validation. Table C.16 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Clinch River stream segment.

Table C.15 Bacteria validation periods, subwatersheds and streams containing stations, and type of bacteria used in the Clinch River watershed study area.

Station	Stream	Validation Period	Subwatershed	Type of Bacteria Used
6BSWO001.81	Swords	10/1/2004 – 9/30/2007	17	E. Coli
6BLWS000.06	Lewis Creek	10/1/2004 – 9/30/2007	16	E. Coli
6BDUM000.04	Dumps Creek	10/1/2004 – 9/30/2007	7	E. Coli
6BEKG004.18	Elk Garden Creek	10/1/2004 – 9/30/2007	10	E. Coli
6BBCD001.89	Big Cedar Creek	10/1/2004 – 9/30/2007	9	E. Coli
6BCLN271.50	Clinch River	10/1/2004 – 9/30/2007	19	E. Coli

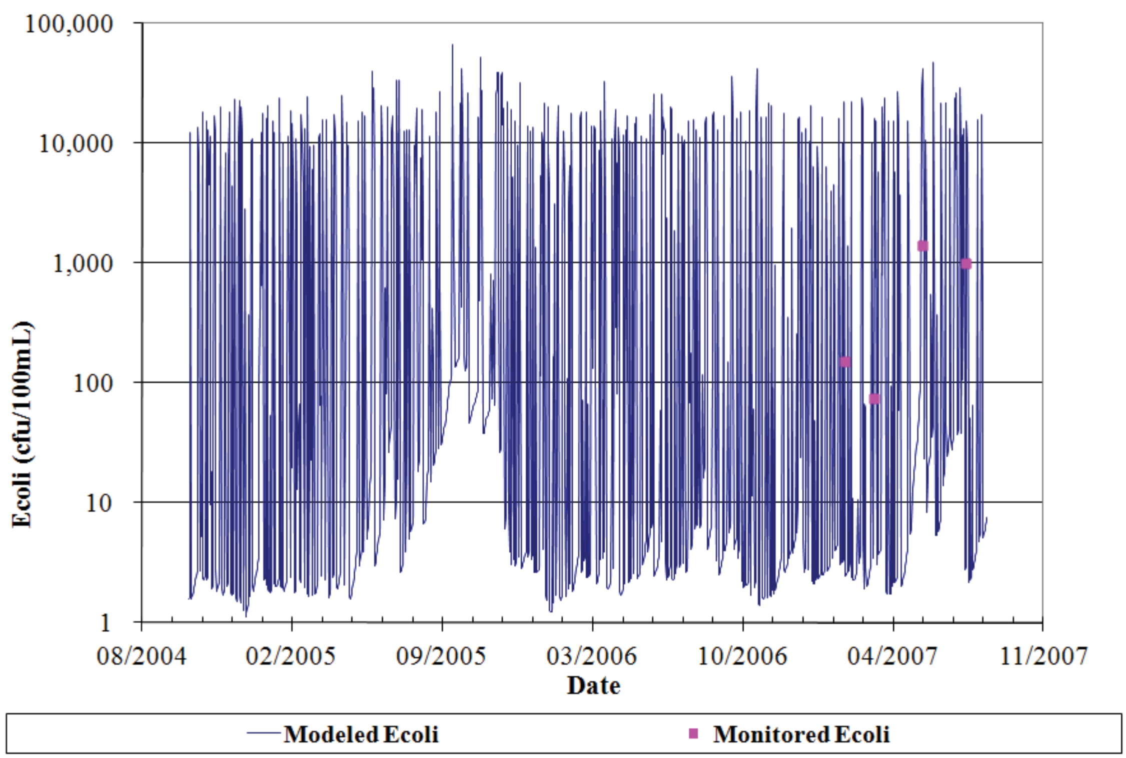

Figure C.39 E. coli validation for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek.

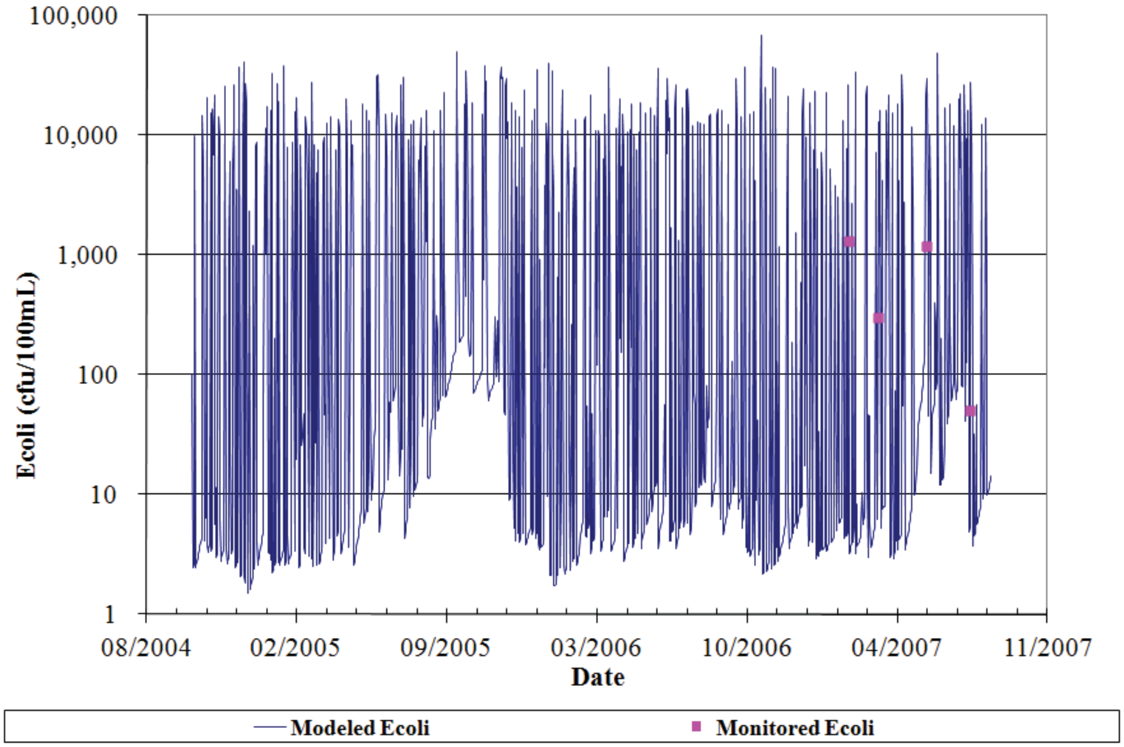

Figure C.40 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek.

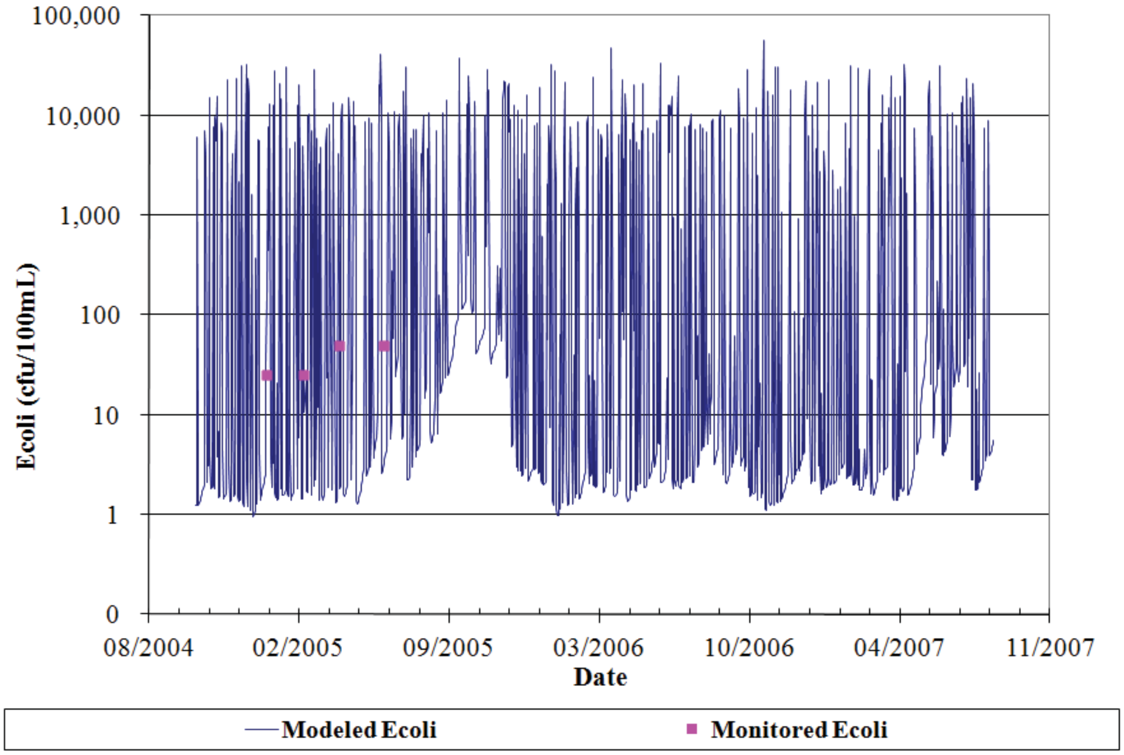

Figure C.41 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek.

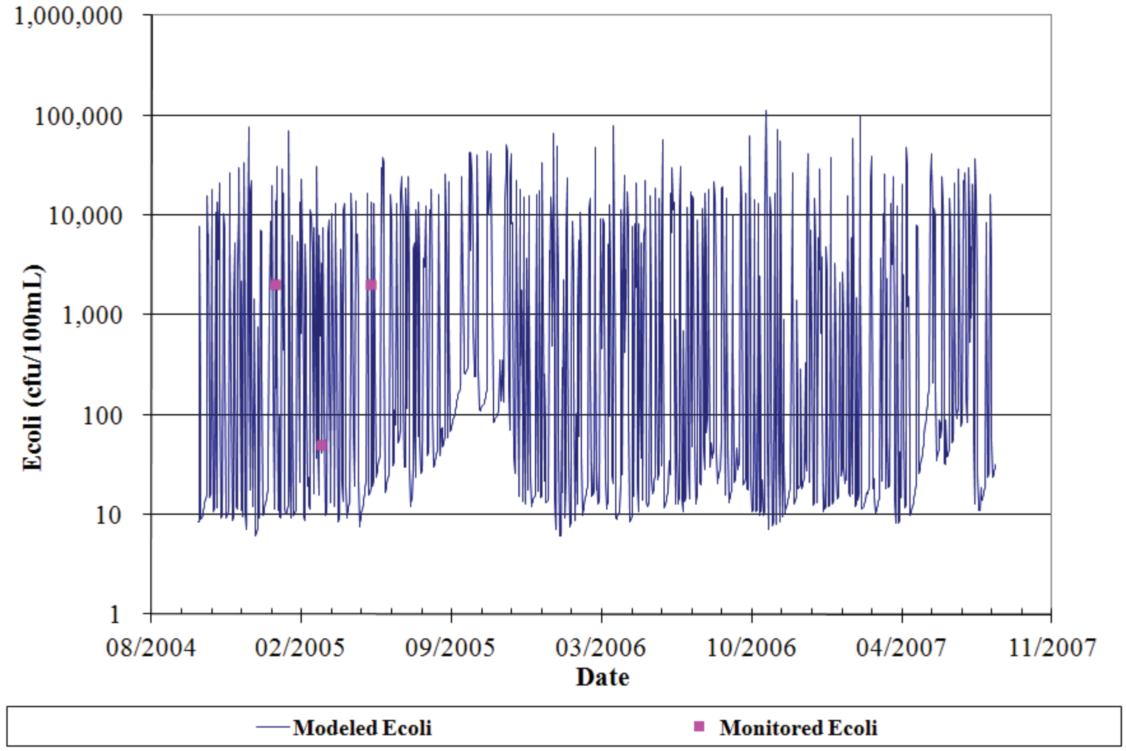

Figure C.42 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek.

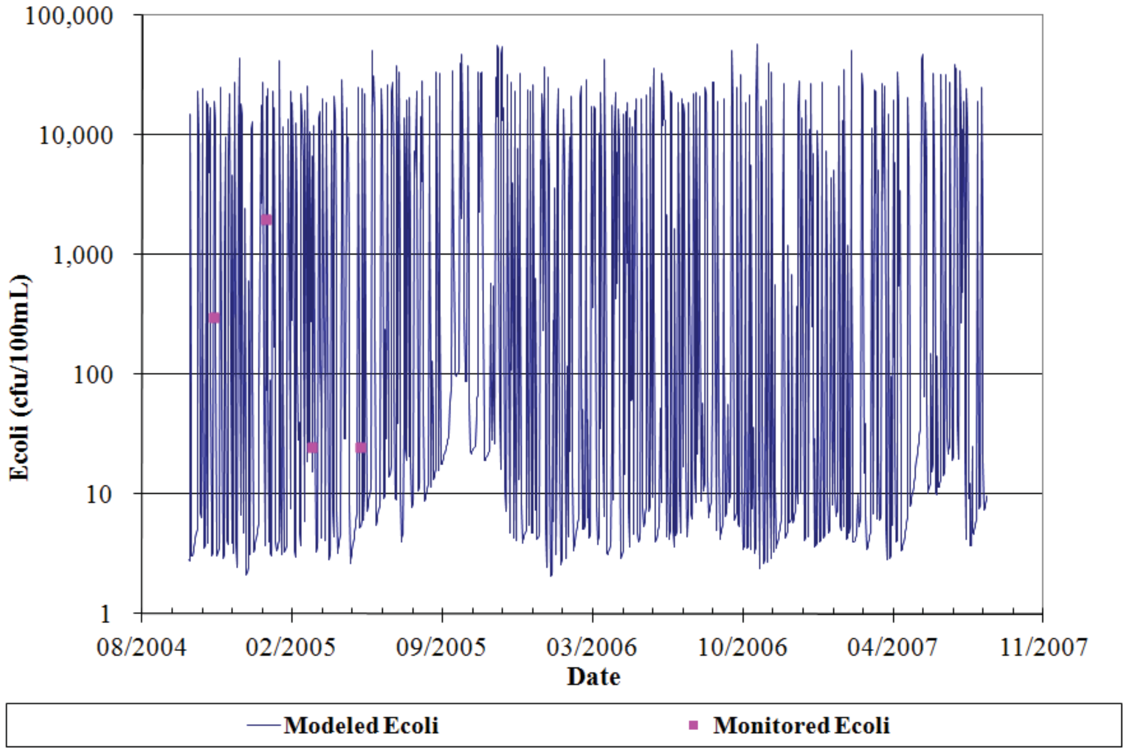

Figure C.43 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek.

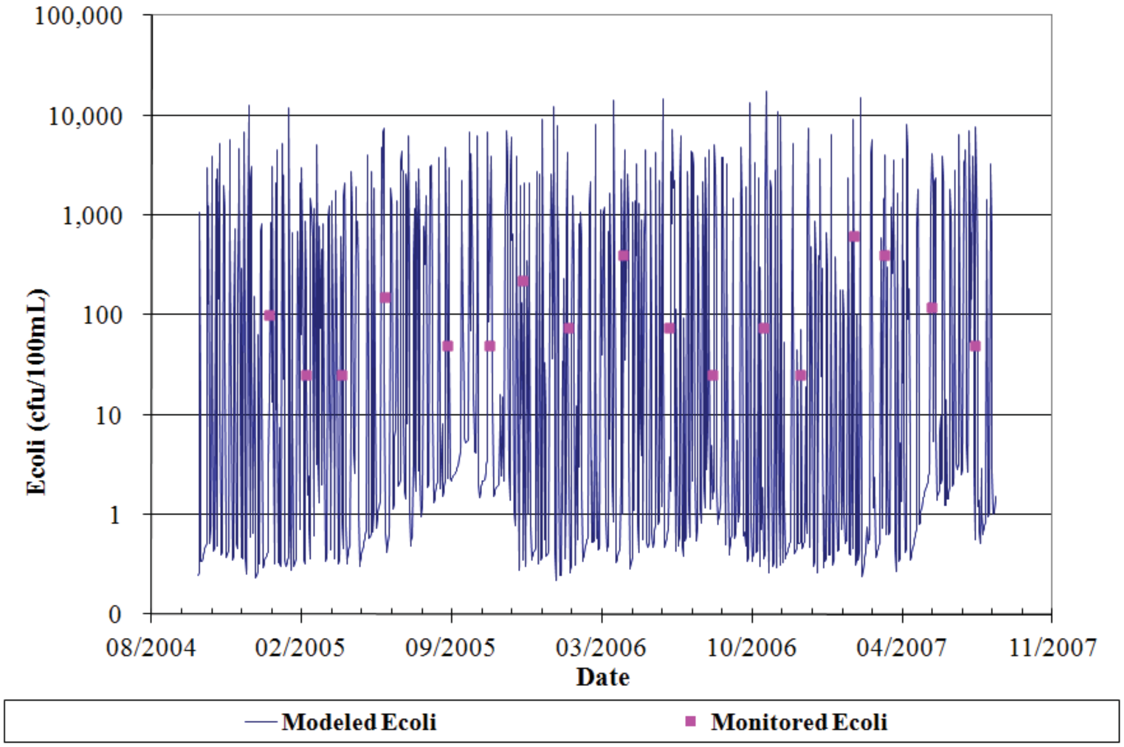

Figure C.44 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River.

Table C.16 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the validation period.

Station	Subwatershed	Maximum Value (cfu/100ml)		Geometric Mean (cfu/100ml)		SS % violations [1]	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BSWO001.81	17	1,400	66,720	354.26	62.01	50%	32%
6BLWS000.06	16	1,300	67,896	391.11	83.39	75%	33%
6BDUM000.04	7	50	57,015	35.36	43.66	0%	30%
6BEKG004.18	10	2,000	112,780	584.80	212.19	67%	41%
6BBCD001.89	9	2,000	58,113	139.16	116.45	50%	37%
6BCLN271.50	19	620	17,467	86.25	66.50	18%	27%

[1] SS = single sample instantaneous standard violations (>235 cfu/100mL for E. coli